FIRE CLAYS
OF
PENNSYLVANIA

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FIRE CLAYS

OF

PENNSYLVANIA

By

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Department of Forests and Waters
C. E. Dorworth, Secretary

Topographic and Geologic Survey
G. H. Ashley, State Geologist

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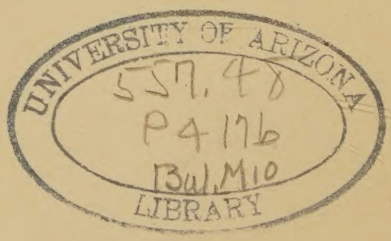

LETTER OF TRANSMITTAL

Charles E. Dorworth, Secretary,
Department of Forests and Waters.

Sir:

I have the honor to submit herewith for publication a report of progress on the Fire Clays of Pennsylvania, by Professor J. B. Shaw, of State College.

Pennsylvania has long led the Nation in the production of fire brick and other refractory products, made necessary by her great iron and steel industry, the metallurgy of other metals, her glass industry, and other industries requiring refractory brick.

In 1923 Pennsylvania produced 444,743,000 fire brick worth $19,208,240.

The present source of fire brick in Pennsylvania is flint clay, of which this State has large quantities. The term "large quantities" is relative, not absolute. The known quantity is so limited, and when found, so lenticular and irregular, that the larger refractories companies have prospecting crews constantly at work with drill and pick, searching for new supplies.

The State Geological Survey has for some time desired to begin a study of these clays, their occurrence, and quantity and character. The recent establishment at State College of a course in ceramics with a ceramic laboratory made a favorable opportunity, and accordingly a cooperative agreement was entered into with Professor Shaw to begin such a study, which was to be pushed forward as fast as funds would allow.

It has seemed best not to delay the publication until the work is completed, but to prepare and submit for publication the results obtained at least every other year. The funds available are not large, so that it is anticipated that the work will be in progress for some years.

This report presents the first results of this work, with an addition of some tests previously made by the U. S. Bureau of Standards, of samples collected many years ago, under the direction of the present State Geologist.

Respectfully.

65651

Geo. H. Ashley

January 24, 1927 State Geologist

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FIRE CLAYS OF PENNSYLVANIA

By J. B. Shaw

INTRODUCTION

Although the clays of various parts of Pennsylvania have been described in several different reports, the descriptions have been limited to small, scattered areas, and all together do not contain the information concerning more than a small fraction of the State's clay resources. Several of the reports are out of print and the descriptions of development are out of date.

The present Geological Survey has frequent requests for information as to the place where clays of specified character can be found, and in order to serve the public, has planned a broad study of the clay resources of the State. This work will require several years. It is planned that clay deposits, mines, and plants will be examined each summer, and the samples collected will be tested during the following winter in the laboratory of the Department of Ceramics, of the School of Mines and Metallurgy, Pennsylvania State College.

Fire clays are mined extensively in this State and high-alumina clays are constantly being sought. Many fire clays have been tested and the results published, especially by Professor Heinrich Ries in U. S. Geological Survey Professional Paper No. 11, issued in 1903. The work so far done, however, is only a beginning. The specifications on fire brick have become so rigid that clays which were used for making refractories a few years ago can no longer be used. Only our fire clays of the highest quality are capable of producing refractories that will pass specifications on No. 1 fire brick, and the search for these clays is being carried on extensively by manufacturers of refractories.

It is well known that enormous quantities of fire clay occur associated with coal beds, but the prevailing general impression that these are all high grade fire clays is wrong. The actual quantity of high grade fire clays in the State appears to be quite limited. While an unlimited quantity of No. 2 and No. 3 fire clays is available, the supply of No. 1 clay does not fill the demand and this condition is not likely to improve. There will always be a good market for No. 1 fire clay.

In the summer of 1925 the writer accepted the proposal of the State Geologist to undertake a report on Pennsylvania's clay re-

sources. Attention was centered on the fire clays for the reasons given above. In outlining the work, due recognition was given to previous work on the fire clays and in collecting samples an effort was made to avoid covering territory from which samples had already been tested and made public. The effort in this direction was not entirely successful but most of the samples collected in 1925 were obtained from localities and deposits which have not heretofore been studied or tested by the State.

Most of the samples were collected by Mr. Geo. Longcor of Marcus Hook, Pennsylvania, an experienced clay sampler, who spent the fall and winter of 1925 in the field. Several samples were sent in by owners of clay deposits and some were collected by the writer. Some samples, as will be seen by the tests, proved not to be fire clay. In every case an effort was made to describe accurately both the geologic and the geographic location from which the sample was obtained.

The laboratory work was done at Pennsylvania State College. Testing the physical properties of the clays was done by Mr. Walter Preische, instructor in ceramics, and David R. Mitchell, graduate assistant in mining engineering. The chemical analyses were made by students in chemistry and ceramics under the supervision of Mr. T. W. Mason, associate professor of analytical chemistry.

This report describes 81 clays, not all of which are fire clay, however. Chemical analyses of 33 of these clays are given. Much work of value can still be done on the fire clays and it is planned to continue the study. This progress report is published for the benefit of all who are interested in the further development of our fire clays, both owners and users.

Whether there are any deposits of diaspore clay in Pennsylvania corresponding with those mined in Missouri is yet to be determined. The nodular clays being worked by some of our manufacturers approach the Missouri diaspore clay quite closely in many of their refractory properties. Larger deposits of nodular clay than are now known probably exist and will add greatly to the value of our fire clay industry when found.

Definition. A fire clay is defined as a clay comparatively free from iron and alkalies, not easily fusible, and therefore suitable for use in making fire brick, blocks, pots, etc. A fire clay may be hard and flint-like, or soft and plastic, but its fusion point must be high. If, as some maintain, a true fire clay is one that fuses above cone 27, then many of the samples tested in this investigation are not fire clay.

PRODUCTION

Pennsylvania has long been a large producer of fire clay, and in most years makes a larger output than any other State. The quantity of fire clay mined annually is not recorded, for much of the clay is made into clay products by the producers themselves. Figures in Mineral Resources of the United States represent chiefly the clay that was mined and sold as clay, and do not include the much larger quantity which was not marketed as raw clay.

From the quantity of fire brick and shapes made in this State it can be computed that the quantity of fire clay used annually is about 1,500,000 tons. Records of the fire clay produced and marketed show that the quantity in recent years has ranged from a quarter to a half million tons, valued on the average at well over a million dollars. This State produces about 20 per cent of the domestic fire clay marketed in the United States, according to the figures in Mineral Resources of the United States.

Fire clay sold by the producers in the United States in 1926

State	Short tons	Value	Avge. value per ton
Alabama	96,490	$ 150,101	$ 1.55
Arkansas	442	2,106	4.76
California	161,898	424,920	2.62
Colorado	172,158	221,393	1.28
Connecticut	435	7,591	17.45
Delaware	1,604	6,416	4.00
Idaho	569	5,787	10.17
Illinois	171,036	343,564	2.00
Indiana	168,263	200,463	1.19
Kentucky	75,801	285,523	3.77
Maryland	22,263	83,295	3.74
Massachusetts	675	25,733	38.12
Mississippi	3,433	32,308	9.41
Missouri	452,449	1,539,271	3.40
Montana	7,552	12,985	1.72
Nebraska	350	1,975	5.64
New Jersey	292,155	1,296,759	4.44
New Mexico	2,118	10,517	5.00
Ohio	302,868	779,842	2.57
Oregon	473	1,009	2.13
Pennsylvania	717,086	2,121,474	2.95
South Carolina	1,769	68,180	38.54
Tennessee	63,691	226,258	3.55
Utah	2,949	16,121	5.46
Virginia	576	2,376	4.12
Washington	1,500	15,381	10.25
West Virginia	63,446	113,007	1.78
Undistributed[1]	35,297	124,968	3.54
	2,819,346	8,119,323	2.88

[1]Includes Georgia, Iowa, Maine, New York, North Dakota, and Texas.

Domestic fire clay marketed in Pennsylvania and in the United States in 1919-1926

	Pennsylvania				United States		
Year	Short tons	Value	Average value per ton	Per cent of U. S.	Short tons	Value	Average value per ton
1919	367,621	$1,089,910	$2.96	20.94	1,755,331	$4,628,605	$2.64
1920	543,610	1,946,772	3.58	23.22	2,341,076	7,425,674	3.17
1921	220,578	713,345	3.22	18.44	1,195,861	3,560,373	2.98
1922	290,701	936,134	3.22	17.31	1,679,220	4,633,486	2.76
1923	412,744	1,172,333	2.84	17.95	2,298,163	6,565,899	2.86
1924	554,257	1,513,286	2.73	22.69	2,443,710	6,737,063	2.76
1925	602,159	1,740,326	2.89	23.80	2,566,934	7,312,349	2.85
1926	717,086	2,121,474	2.95	25.43	2,819,346	8,119,323	2.88

Fire clay is used for a great variety of purposes, as shown by the following table from Mineral Resources of the United States.

Domestic fire clay sold in the United States in 1923-1925, by uses, in short tons.

	1923	1924	1925
White-bodied ware, including china and porcelain	3,791	15,789	15,401
Art pottery	339	5,677	283
High-grade tile	8,579	12,705	20,469
Chemical stoneware	1,906	825	872
Stoneware	8,740	12,450	16,447
Enameling	120	120	-------
Rubber	-------	1,300	-------
Paper filler	445	-------	200
Paint filler or extender	150	160	-------
Architectural terra cotta	72,691	27,543	38,763
Asbestos products	1,102	2,002	2,032
Plaster and plaster products	16,893	13,300	15,423
Cement	-------	28,775	35,731
Artificial abrasives	5,355	695	1,116
Saggers	160,457	187,472	144,770
Pins, stilts, and spurs for potter's use	7,759	5,619	4,720
Wads	28,289	28,723	27,032
Gas retorts	15,264	2,480	4,849
Fire brick and block	590,282	810,458	802,906
Fire clay mortar	442,198	329,891	399,609
Bauxite and high-alumina brick	2,672	-------	-------
Glasshouse pots	19,642	30,060	43,410
Glasshouse supplies, blocks, tiles, etc.	39,445	11,243	8,140
Zinc retorts and condensers	41,302	47,454	58,924
Clay crucibles	4,643	27,242	
Graphite crucibles and stoppers	2,080	1,770	2,332
Foundry use and steel works for cupola lining	515,619	440,589	480,729
Unspecified	308,400	399,358	441,851
	2,298,163	2,443,710	2,566,934

By this table showing the various uses of domestic fire clay sold in the United States it is made clear that nearly one-half of the fire clay is used in making fire brick, blocks, and mortar. Another

outstanding large use of fire clay is for cupola lining in foundries and steel works. These are the principal purposes for which Pennsylvania fire clay is sold.

TESTS ON THE CLAYS

Sampling. About 90 per cent of the samples here reported were collected by Mr. George Longcor. He was instructed to collect enough samples from each deposit of clay to enable us to get an accurate estimate of the quality of the clay. If the bed of clay varied perceptably from top to bottom, he was to take a sample representing each layer of the strata that had perceptibly different physical properties. He was instructed to follow a uniform method of sampling in so far as it was possible, each sample to be obtained by cutting a groove from top to bottom of the portion of the stratum being sampled. Each sample weighed about ten pounds.

While local conditions make it sometimes difficult or impossible to follow fixed rules, it is assumed that in general the samples were collected as above outlined. All clay samples submitted were tested and the conclusion drawn from the data obtained presuppose that the samples are fully representative of the strata from which taken. The reliability of the data obtained depends more upon the efficiency of the sampling than on any other step.

Grinding. All samples were ground sufficiently fine to pass a 20-mesh screen. A disc pulverizer was used for final grinding, those clays requiring it being previously crushed in a jaw crusher to approximately ½ inch size.

Clays which had no magnetic iron as submitted were treated with a magnet to take up any metallic iron picked up in crushing and grinding. A few clays had some magnetic iron as received; they were not treated with the magnet.

Samples submitted to the chemical laboratory for analysis were carefully treated with the magnet.

Raw, green, and burned clay. Clays are commonly spoken of as passing through three states or stages from clay bank to finished product.

The raw state refers to the clay as it is in the bank or bin before grinding or weathering. In this state the original characteristics of the clay are still evident.

The green state refers to the clay after grinding but before burning.

The burned or fired state refers to the clay after it has been subjected to heat somewhat higher than that used for drying. At the end of the drying period clay is still in the green state.

TESTS IN THE RAW STATE

The samples in the raw state were examined to determine the color, hardness, fracture, and visible foreign matter. Color includes white, and shades of gray and brown. Hardness is described roughly by the terms, hard, medium, and soft. Fracture is of three kinds, earthy, conchoidal, and splintery. Visible foreign matter includes such impurities as iron, carbon, and sulphur compounds.

TESTS IN THE GREEN STATE

Plasticity. After grinding through a 20-mesh screen the samples were mixed with sufficient distilled water to produce normal consistency. By normal consistency[1] is meant that condition in which the clay is most workable, is no longer sticky, and will not adhere to metal. The "feel" of the clay at or near normal consistency, estimated by the operator, is the basis on which it is rated as having good, poor, or fair plasticity. This test was made in every case by the same man, thereby eliminating as far as possible the error introduced by the personal factor.

Water of plasticity. With the clay at normal consistency, sixteen briquettes were made, approximately 1 by 1 by 2 inches, by pressing the clay in a brass mold and cutting to proper length with fine wire. These briquettes were weighed accurately to 1/10 gram. Their volume was accurately determined in a volumeter, using kerosene oil. All briquettes were dried to approximately constant weight at 110° C. After cooling to room temperature in a desiccator, they were weighed immediately. Water of plasticity was calculated using the formula:

$$\text{Per cent water of plasticity} = \frac{\text{Wet weight} - \text{Dry weight} \times 100}{\text{Dry weight}}$$

This gives water of plasticity in terms of weight of dry clay.

Shrinkage water. The volume of the briquettes was determined by the method worked out by Crawford.[2] This method involves saturation of only two or three of the dried briquettes with kerosene. These may be discarded and thus avoid some of the difficulties encountered in burning kerosene soaked briquettes. Booze found this method satisfactory and used it in his trials of American fire clays.[3] In the method referred to the dry volume of the test piece is determined by the formula:

$$\text{Dry volume in cc.} = \frac{\text{Dry weight in grams}}{\text{Specific gravity}}$$

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[1] Kinnison, C. S., A study of the Atterbury plasticity method: U. S. Bureau of Standards Tech. paper 46, p. 4, 1915.

[2] Crawford,—A simplified method of determining the dry volume of clay briquettes: Jr. Am. Cer. Soc., Vol. 5, p. 394, 1922.

[3] Booze, M. C., The chemical and physical properties of fire clays from various producing districts: Jr. Am. Cer. Soc., Vol. 8, p. 655, 1925.

Having thus calculated the dry volume of each briquette, the shrinkage water is calculated by use of the formula:

$$\text{Per cent shrinkage water} = \frac{\text{Wet volume in cc.—Dry volume in cc.} \times 100}{\text{Dry weight in grams}}$$

This formula makes use of the fact that 1 cc. of water weighs 1 gram.

Pore water. The pore water is calculated from the formula:

$$\text{Per cent pore water} = \text{per cent water of plasticity} - \text{per cent shrinkage water.}$$

Drying shrinkage. Drying shrinkage in terms of dry volume was calculated from the formula:

$$\text{Per cent drying shrinkage} = \frac{\text{Wet volume} - \text{Dry volume} \times 100}{\text{Dry volume}}$$

Linear drying shrinkage was determined by molding a bar 1″ by 1″ by 6″, striking off two marks on the wet bar 10 centimeters apart, drying the bar at 110° C, measuring the distance in centimeters between the original marks and computing the shrinkage by use of the formula:

$$\text{Per cent linear drying shrinkage} = \frac{\text{Wet length (10cm)—Dry length} \times 100}{\text{Dry length}}$$

Time of slaking. Two 1 inch cubes were made of the clay at normal consistency, dried at 110° C., and placed on a 4-mesh wire screen immersed in water to such depth that the top of the cube was just out of the water. The bottom of the cube on the screen was 1 inch above the bottom of the pan. The water was at 15° C. and care was taken to avoid vibration of the pan or cube during the period of slacking. The time required for practically all of the clay to fall through the screen was recorded as time of slacking.

TESTS IN THE FIRED STATE

The briquettes which had been used in determining drying shrinkage were fired at 50° intervals from 1000°C. to 1400°C. The burned briquettes were accurately weighed, saturated with distilled water by boiling 2 hours and soaking 24 hours, weighed, and volume determined in a volumeter using distilled water.

From the data thus obtained porosity, burning shrinkage and apparent specific gravity were determined by using the following formulas:

$$\text{Apparent porosity} = \frac{\text{Saturated weight—Dry weight} \times 100}{\text{Fired volume}}$$

$$\text{Per cent burning shrinkage} = \frac{\text{Dry volume green—Volume fired} \times 100^*}{\text{Dry volume green}}$$

$$\text{Apparent specific gravity} = \frac{\text{Dry weight fired} \times 100}{\text{Volume fired—(Saturated weight fired—Dry weight fired)}}$$

Fusion point. The term fusion point is used in preference to softening point as it seems to describe more clearly what actually happens when a cone bends over as a result of heat. It is quite generally understood that clays do not have a definite melting point such as metals have. When heated the individual minerals in a clay become fluid and partly dissolve grains of less fusible materials. As the temperature is increased the quantity of the fluid increases in proportion to the solids and the viscosity of the fluid portion decreases. When the viscosity of the mass is reduced to a point where the force of gravity overcomes its resistance to flow, the cone bends over or squats on the pat. The temperature at which the tip of the cone touches the pat supporting it is recorded as the fusion point. These temperatures are measured by use of standard cones whose fusion temperatures have been previously determined by means of accurate temperature measurement devices.

The fusion point of the clays was determined by use of an oxy-acetylene burner in a specially constructed furnace lined with a mixture of alundum cement 15 per cent and fused alumina 85 per cent. The cones were set in cone pats made of the same mixture. Experience in recent years has shown that the fusion point must be made under accurately controlled furnace conditions if serious error is to be avoided.

CHEMICAL ANALYSIS

The chemical analysis of a clay is a long, tedious process and hence necessarily expensive. It has been found that the physical properties bear so little relation to the chemical composition that not much information of practical value can be deduced from the chemical analysis. From the practical standpoint, the manufacturing process must deal largely with the physical properties. For these reasons, the chemical analysis of clay is not frequently made. In estimating the value of a fire clay for some purposes, the chemical

* In cases when the test pieces swell in firing so that their fired volume is greater than their dry volume, the value obtained from this equation is negative.

analysis is of considerable assistance and hence the chemical composition of fire clays is more frequently determined than of other types of clay.

The analyses of these clays were made by students of the Departments of Ceramics and Chemistry at Pennsylvania State College. It is entirely probable that these analyses are sufficiently accurate for all practical purposes, although it is possible that the percentages given of TiO_2, Fe_2O_3, and alkalies, in some instances are quite inaccurate.

CLASSIFICATION OF FIRE CLAYS

Fire clays, as the name implies, are clays which withstand high temperatures. Their principle use is in the manufacture of refractories such as fire brick, furnace brick, flue linings, etc. Not all fire clays are capable of withstanding sufficient heat to justify their use for the production of fire brick. Such clays frequently do, however, have good manufacturing properties and where present in sufficient quantity and favorably located with regard to fuel, labor, and market, are made into paving brick, sewer pipe, hollow tile, terra cotta, etc. In order to determine the purpose for which a given fire clay can be used, it is necessary to make such tests as have been made on these clays and then study the properties of the clay as indicated by the data obtained. Fusion point and other physical properties are bases of classification.

By fusion point. A classification suggested by A. V. Bleininger[1] has been widely used. This classification requires that a No. 1 fire clay shall not fuse below cone 31 or about 1685° C. Fire clays which have a fusion point between cone 28 and 31 are classified as No. 2 fire clays, and those having fusion point below cone 28 or about 1635° C. are considered No. 3 fire clays.

By hardness and plasticity. Fire clays are generally classified as flint clay, plastic clay, and semi-flint clay.

Flint clay is hard and rock-like, having sharp edges, conchoidal fractures, and may be any color from nearly white to black. It does not develop into a plastic mass easily molded into shape when mixed with water; when ground with water to a fine powder it acts much like ganister or sand.

Plastic clay is generally quite easily cut with a knife, though it may be solid and even hard to cut. It readily softens when placed in water and when mixed with just enough water to make a dough-like mass it is readily molded into any desired form.

[1] Bleininger, A. V., Some aspects of the testing of refractories: The Engineers Society of Western Pennsylvania, vol. 32, p. 613, 1916.

Semi-flint clay is midway between flint clay and plastic clay. It may be very hard and rock-like or soft and easily pulverized. It never develops much plasticity or moldability, and does not slake readily, if at all. It never has the sharp flinty fracture shown by the flint clay. Semi-flint clay is in general of less value than either plastic or flint clay, though in some cases its fusion point is high enough to admit of its use for the production of refractories. In a few exceptional cases semi-flint clays have been the principal clays used in high grade fire brick.

By porosity. The porosity of fire clays when fired at different temperatures is the basis of classification sometimes used.[1] Curves showing the upper and lower limits of porosity at varying temperatures fix the boundary of the field of No. 1, No. 2, and No. 3 fire clays.

[1]Purdy, R. C., Paving brick and paving brick clays of Illinois: Illinois Geological Survey Bull. 9, pp. 271-278, 1908.

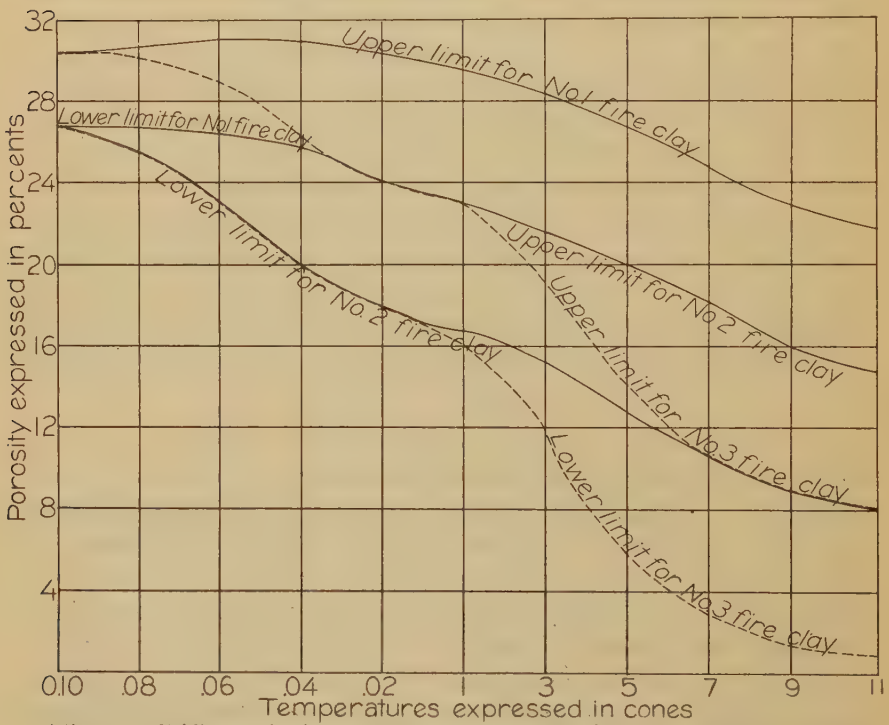


Fig. 1. Differentiation of fire clays on basis of porosity changes.

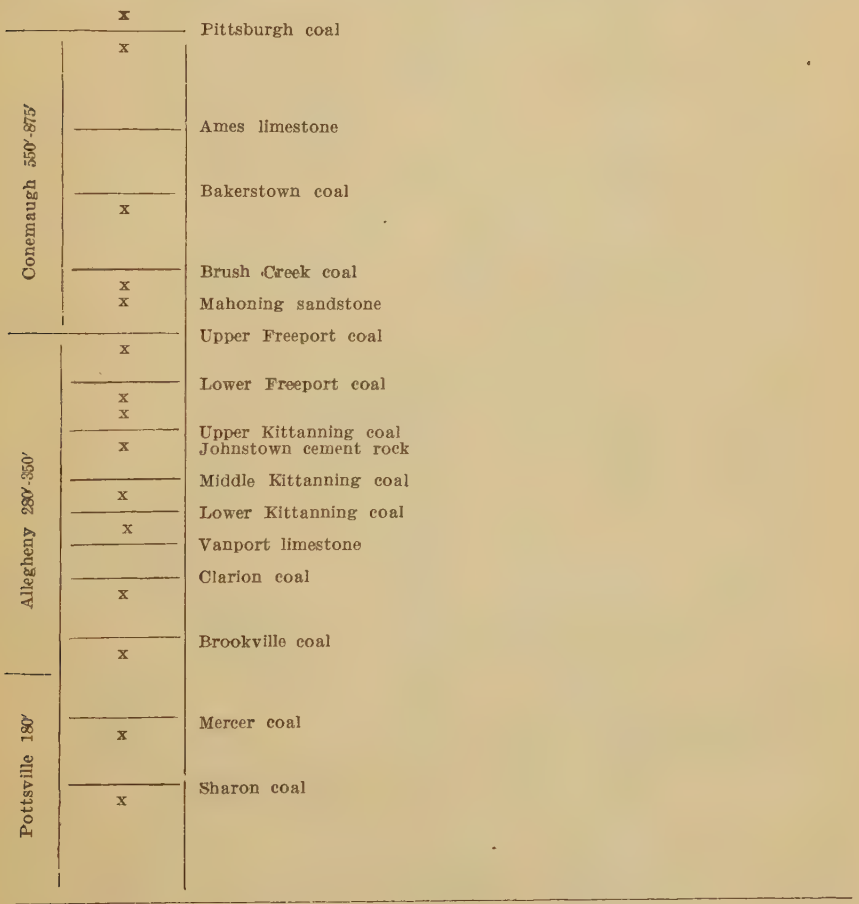
By comparing the curves for any of the following clays with the curves on the chart it will be seen that most of the clays here reported fall within their proper field on the chart.

DESCRIPTION OF SAMPLES

The geographic distribution of the localities where clay samples were collected in 1925 is shown on the accompanying map, and ranges from the Northern Anthracite field in Wyoming County on the northeast to Fayette County on the southwest.

The geologic relation of the beds from which the samples were taken ranges from the top of the Pittsburgh coal to the underside of the Sharon coal, as shown in the following diagram.

Generalized geologic section showing position (x) *of material tested.*



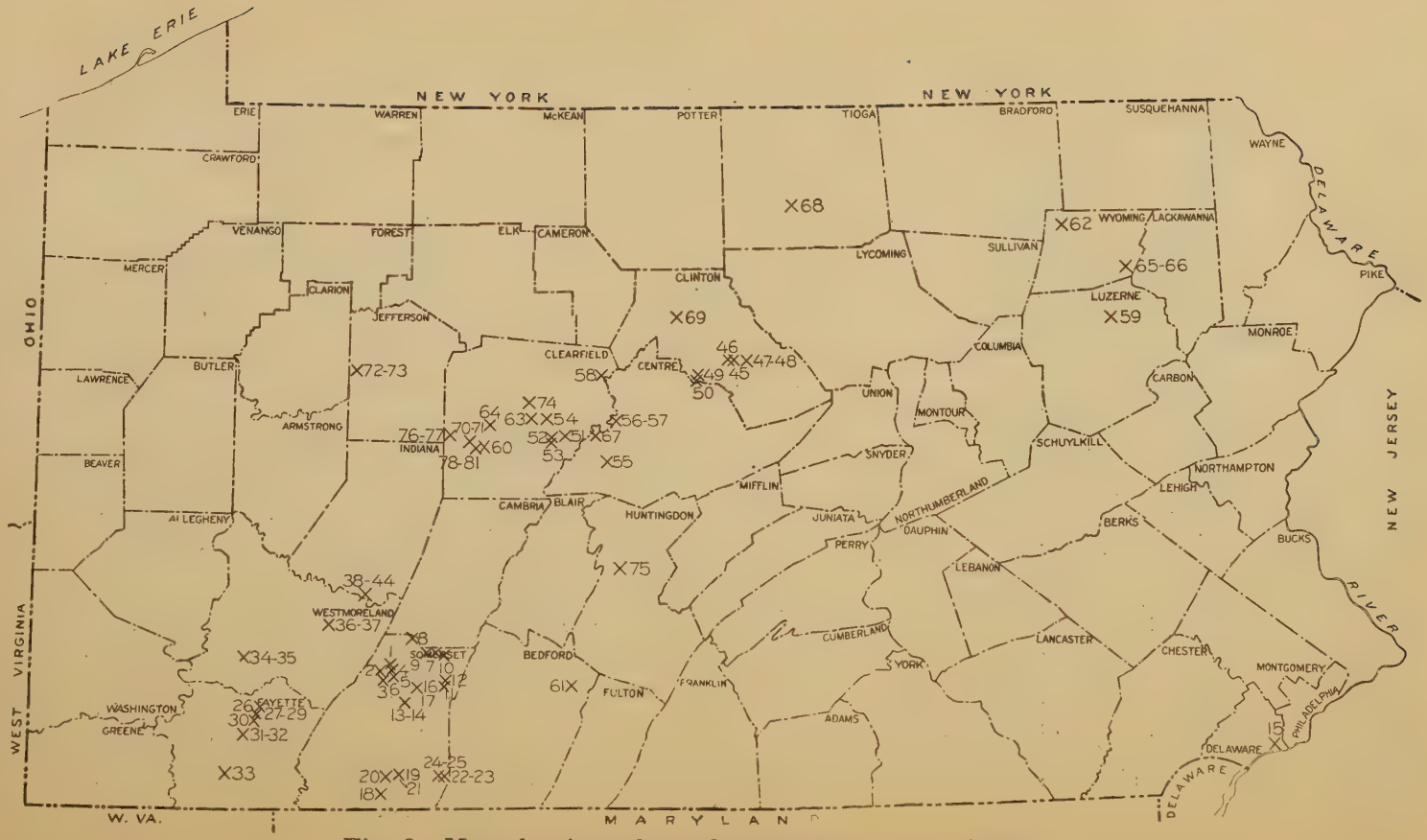


Fig. 2. Map showing where clay samples were collected.

List of samples

No.	Kind of clay	Coal near clay	County	Owner
1.	Semi-flint	Upper Kittanning	Somerset	Davis Coal & Coke Co.
2.	" "	Lower Freeport	"	Edmund Gonder
3.	Flint	Upper Freeport	"	Geo. Wichpenheiser
4.	Semi-flint	" "	"	Edmund Gonder
5.	Plastic	Pottsville sandstone	"	R. D. Phillipi
6.	Semi-flint	Middle Kittanning	"	Vacant lot
7.	Semi-flint	Clarion	"	Windber Brick Works
8.	" "	Cement rock	"	Valley Smokeless Coal Co.
9.	Shale	Brookville	"	Phillips Coal Co.
10.	Flint	Lower Kittanning	"	Egolf Coal Mining Co.
11.	Shale	" "	"	Loyal Hanna Coal & Coke Co.
12.	Semi-flint	Clarion	"	Arrow Coal Mining Co.
13.	Flint	Upper Kittanning	"	J. M. Lambert
14.	Shale	Lower Freeport	"	" "
15.	Cyanite		Delaware	Geo. Longcor
16.	Shale	Upper Freeport	Somerset	Jos. Birkeypile
17.	Shale	Lower Freeport	"	" "
18.	Shale	Pittsburgh	"	C. K. Bowman & Co.
19.	Plastic	Mercer	"	R. H. Whitford
20.	Plastic	Pittsburgh	"	Consolidation Coal Co.
21.	Flint	Lower Mercer	"	Keystone Fire Brick Co.
22.	Flint	Sharon	"	Savage Brick Co.
23.	Plastic	"	"	" " "
24.	"	"	"	Lewis M. Neld
25.	"	Upper Mercer	"	" " "
26.	Flint	Upper Freeport	Fayette	Joseph Soisson Fire Brick Co.
27.	Semi-flint	Brush Creek	"	" " " " "
28.	Flint	" "	"	" " " " "
29.	Plastic	Upper Freeport	"	" " " " "
30.	"	Mahoning sandstone	"	Along railroad
31.	Flint	Brush Creek	"	Eureka Fire Brick Co.
32.	Plastic	Upper Kittanning	"	" " " "
33.	"	Sharon	"	Fayette Fire Brick Co.
34.	Semi-flint	Upper Freeport	Westmoreland	Westmoreland Fire Brick Co.
35.	Flint	" "	"	" " " "
36.	Plastic	Sharon	"	Joseph Soisson Fire Brick Co.
37.	Semi-flint	"	"	" " " "
38.	Plastic	Upper Mercer	Indiana	Garfield Fire Brick Co.
39.	"	Lower Kittanning	"	Joseph Soisson Fire Brick Co.
40.	"	Upper Mercer	"	Garfield Fire Brick Co.,
41.	Plastic	" "	"	Joseph Soisson Fire Brick Co.
42.	Flint	" "	"	" " " " "
43.	Plastic	Lower Kittanning	"	" " " " "
44.	"	" "	"	" " " " "
45.	Flint	Upper Kittanning	Clinton	Stowe-Fuller Refractories Co.
46.	Plastic	Brookville	"	" " "
47.	Flint	"	"	Queens Run Refractories Co.
48.	Plastic	"	"	" " " "
49.	Flint	"	"	Harbison-Walker Refractories Co.
50.	Plastic	"	"	" " " "
51.	"	Clarion	Clearfield	General Refractories Co.
52.	Semi-flint	Sharon	"	" " "
53.	Flint-nodule	"	"	" " "
54.	Plastic	Clarion	"	" " "
55.	Semi-flint	Sharon	Centre	" " "
56.	" "	Lower Mercer	"	" " "
57.	Plastic	" "	"	" " "
58.	"	" "	Clearfield	" " "
59.	Semi-flint	Ross	Luzerne	L. H. Atherholt
60.	Shale	Lower Freeport	Clearfield	Robert L. Derrick
61.	Semi-flint	Bakerstown	Bedford	Kay Coal Mining Co.
62.	Shale	"	Wyoming	Lewis B. Carter
63.	Plastic	Mercer	Clearfield	Harbison-Walker Refractories Co.
64.	Flint-nodule	Brookville	"	" " " " "
65.	Red clay	"	Wyoming	C. A. Van Tuyl
66.	" "	"	"	" " "
67.	Plastic	Clarion	Clearfield	Morning Star & Schnars Coal Co
68.	Red shale	Pottsville	Tioga	Fred A. Graham
69.	Flint	Brookville	Clinton	Geo. H. Smith
70.	Plastic	Lower Kittanning	Clearfield	D. F. Bell
71.	Flint	" "	"	" "
72.	Plastic	Clarion	Jefferson	Hanley Ceramics Co.
73.	"	"	"	" " "
74.	"	Middle Kittanning	Clearfield	Robinson Clay Products Co.
75.	"	Oriskany sandstone	Huntingdon	G. I. Phillips
76.	"	Lower Freeport	Clearfield	Madeira Hill Coal Mining Co.
77.	Shale	" "	"	" " " "
78.	"	" "	"	Good Coal & Clay Co.
79.	Flint	Brookville	"	Passmore Estate
80.	"	Clarion	"	Hoyt Estate
81.	Shale	Lower Kittanning	"	Robert L. Derrick

Samples listed by counties.

Bedford, 61
Centre, 55-57, 67
Clearfield, 51-54, 58, 60, 63, 64, 70, 71, 74, 76-81.
Clinton, 45-50, 69
Delaware, 15
Fayette, 26-33
Huntingdon, 75
Indiana, 38-44
Jefferson, 72, 73
Luzerne, 59
Somerset, 1-14, 16-25
Tioga, 68
Westmoreland, 34-37
Wyoming, 62, 65, 66

Sample No. 1. Somerset County, Jenner Township: A semi-flint clay owned by the Davis Coal and Coke Co., Boswell, Pa. It was obtained in an abandoned clay pit 75 feet from the main road just west of Boswell. Four feet of clay is exposed along the outcrop of coal in this valley and may underlie all the coal. The clay is fine grained, hard and shows no weathering; it is drab in color, unoxidized, has no surface stain, and is divided into four different layers, with slight difference in structure and color. It underlies the Upper Kittanning coal in the Allegheny group. The country is hilly, the clay outcropping along the side of a hill. Railroads are easily accessible, as they serve the coal mines here; fuel is easily available and mining towns nearby supply labor. The clay is undeveloped and is not utilized. The sample shows an earthy fracture; is slate colored, has medium hardness, a trace of iron, and short plasticity.

The data obtained indicate that this clay could be successfully used in the production of refractories. It is a No. 1 fire clay.

Sample No. 2. Somerset County, Jenner Township: a semi-flint clay owned by Edmund Gonder, Boswell, Pa. It was obtained along the rib of the main entry of the Kelley coal mine at Boswell, 250 feet from the mine mouth. The clay underlies all the coal in this section as far as can be ascertained. The clay is nodular, burley and sandy; it is 3 feet 6 inches thick, dark gray to black and is uniform throughout. It underlies the Lower Freeport coal of the Allegheny group. Railroads are easy of access, fuel is easily available. and labor is supplied from mining towns nearby. The clay

is undeveloped and is not utilized. The sample shows a conchoidal fracture, is gray, has medium hardness, and short plasticity.

The data obtained indicate that this is a No. 3 fire clay and could be used for production of face brick or tile.

Sample No. 3. Somerset County, Jenner Township; a flint clay owned by Geo. Wichpenheiser, Jenners, Pa. It was obtained along the southwest side of the Lincoln Highway 125 yards northwest of the bridge crossing Quemahoning Creek near Jenners. The clay underlies the Upper Freeport coal, and is under soft clay which lies next to the coal. The clay has a smooth texture on the surface of the fracture; it is 5 feet thick, drab to dark gray in color, oxidized, and varies from soft plastic on top to flint on the bottom. Railroads are easily accessible, fuel is easily available, and labor is plenty. The clay is undeveloped and is not utilized. The sample shows a conchoidal fracture, is gray, has medium hardness, and short plasticity.

The data obtained indicate that this is a No. 1 flint clay and could be successfully used in production of refractories.

Sample No. 4. Somerset County, Jenner Township: a semi-flint clay owned by Edmund Gonder, Boswell, Pa. It was obtained on the farm of Edmund Gonder about 2 miles from Jenners Cross Roads. The clay underlies the entire farm. It is nodular in structure, 5 feet thick, nearly black, oxidized, and has an iron rust surface stain. Its upper and lower portions are soft. The clay lies between the Upper and Lower Freeport coals. The country is hilly; the B. and O. railroad is near, both fuel and labor are available. The clay is undeveloped and unutilized. The sample shows a conchoidal and splintery fracture; is gray, has medium hardness contains some iron, and has short plasticity.

The data obtained indicate that this clay is of doubtful economic value. Its low melting point is doubtless due to high alkalies and lime. It might be used for production of brick or tile.

Sample No. 5. Somerset County, Jenner Township: a plastic clay owned by R. D. Phillipi, Boswell, Pa. It was obtained under a quarry floor a short distance southeast of Boswell. The clay lies along an unconformable bedding plane in the Pottsville (?) sandstone. The clay lightens in color when dry; is soft and breaks easily. It is brownish, oxidized, and is found in pockets 8 to 30 inches thick and 10 to 40 feet long. The utilization of this clay is not an economic proposition due to its pockety occurrence. The clay is undeveloped and unutilized. The sample submitted shows

an earthy fracture; is light gray, soft, contains some iron, and has very good plasticity.

The data obtained indicate that this clay has no value as a refractory. Its sudden shrinkage at about 1150° C. would make it difficult to burn commercially.

Sample No. 6. Somerset County, Jenner Township: a semi-flint clay located in a vacant lot in the town of Boswell, Pa., and extending along the Jenners-Boswell road. The clay is soft and plastic, 5 feet thick, white and brown in color. Where the clay is oxidized it shows a surface stain of iron. It is soft on top and burley on the bottom. It underlies the Middle Kittanning coal bed. The clay is undeveloped and unutilized. The sample submitted shows a conchoidal and splintery fracture, is blue gray, has medium hardness, contains some iron, and has short plasticity.

The data obtained indicate that this clay has little if any economic value. Its short vitrification range together with the fact that it overfires badly at about 1300° C. renders it of little value as a refractory.

Sample No. 7. Somerset County, Paint Township: a semi-flint clay owned by Windber Brick Works, Windber, Pa. It was obtained at the base of a hill, outcropping for 150 yards in the southeastern part of Windber. The clay underlies 45 acres; it is rough and burely in texture, 6 feet thick, dark gray, oxidized, has an iron surface stain and is homogeneous. It underlies the Clarion coal. The country is hilly; the railroad facilities are good; fuel is plenty (4 beds of coal) and labor is plentiful. The clay is mined underground by the room and pillar method and is handled by mine railroads. Development was started in 1901. The clay is used for the manufacture of paving brick and fire brick. The sample shows a conchoidal fracture; it is gray, medium hard, has a trace of iron, and short plasticity.

The data obtained indicate that this is a No. 2 fire clay with rather low temperature of vitrification.

Sample No. 8. Somerset County, Conemaugh Township: a semi-flint clay owned by the Valley Smokeless Coal Co., Windber, Pa. It was obtained in a railroad cut, along a wagon road, 1 mile west of bridge crossing Stony Creek, west of the village of Kring. The clay crops out for 175 yards and weathers easily; it is 3 feet thick and homogeneous. The bed is in Johnstown cement rock. The country is hilly and the clay is exposed in a deep railroad cut. Railroads are near; both fuel and labor are plentiful. The clay is

undeveloped and unutilized. The sample shows a conchoidal and splintery fracture; it is blue gray, medium hard, has a trace of iron, and short plasticity.

The data obtained indicate that this clay is of doubtful economic value. Its sudden shrinkage at 1150° C. renders it difficult to burn commercially.

Sample No. 9. Somerset County, Paint Township: a shale owned by the Phillips Coal Co., Scalp Level, Pa. It was obtained from the rib of the entry in the No. 30 mine of the Berwind-White Co. near Scalp Level. The shale is hard, massive, and has a fine grain and slighty gritty texture. It is 4 feet 6 inches thick, dark gray, unoxidized, and has no surface stain. The bed is homogeneous and has no joint or bedding plane, and underlies the Brookville coal. The country is very hilly. Railroads are near; fuel is plentiful and labor satisfactory. The shale is necessarily mined in large quantities with the coal but is not utilized. The sample shows a conchoidal fracture; is blue gray, very hard, has a trace of iron, and short plasticity.

The data obtained indicate that this shale, which looked so much like a flint clay and was submitted for test as such, cannot be successfully used for production of a ceramic product. Its fired properties resemble those of some other shales.

Sample No. 10. Somerset County, Paint Township: a flint clay owned by the Egolf Coal Co., Windber, Pa. It was obtained from a coal mine located ½ mile north of the village of Rummel. Only the upper 2 feet of this clay were sampled; the bed may be thicker. It underlies the Lower Kittanning coal. The country is hilly, railroads are near, both fuel and labor are plentiful. The clay is undeveloped and unutilized. The sample shows a splintery fracture; is blue gray, very hard, and has short plasticity.

The data obtained indicate that this is a No. 1 fire clay which could be successfully used for the production of refractories.

Sample No. 11. Somerset County, Shade Township: a shale owned by the Loyal Hanna Coal & Coke Co., Cairnbrook, Pa. It was obtained 2 miles inside a mine mouth in the town of Cairnbrook. The shale has a smooth, fine grain, is 6 feet 5 inches thick, light drab to blue, oxidized on exposed surface, and has a surface stain of $FeSO_4$; it is plastic on top and bottom and shale in the middle. It underlies the Lower Kittanning coal. The country is hilly, railroads are near, coal and labor are plentiful. The shale is undeveloped and unutilized. The sample shows a splintery fracture, is blue gray, very hard, has a trace of coal, and short plasticity.

The data obtained indicate that this sample, while exhibiting some of the properties of a flint clay, should be classed as a shale from its chemical analysis and sudden fusion. It has no economic value as a clay.

Sample No. 12. Somerset County, Shade Township: a semi-flint clay owned by the Arrow Coal Mining Co., Cairnbrook, Pa. It was obtained ½ mile northeast of Cairnbrook. The clay extends ½ mile along the branch line of the Pennsylvania Railroad running from Windber to Central City. The clay is slightly granular and rough; it is 4 feet 6 inches thick, gray, unoxidized, has a slight surface stain, and is homogeneous and regularly bedded. It underlies the Clarion coal. Railroads are near; both fuel and labor are plentiful. There is ample room for development and plant. The clay is undeveloped and unutilized. The sample submitted shows a conchoidal and splintery fracture, is gray, medium hard, has a trace of iron, and short plasticity.

The data obtained indicate that this is a No. 3 fire clay having fair burning properties, which might be used for production of refractories.

Sample No. 13. Somerset County, Quemahoning Township: a flint clay owned by J. M. Lambert, Coleman, Pa. It was obtained along the Johnstown and Rockwood Branch of the B. & O. R. R. halfway between Coleman and Kimmelton, outcropping in scattered fragments on a hillside. The clay is blocky, fine grained and smooth; its thickness is undetermined; it is light drab to dark gray and unoxidized. It underlies the Upper Kittanning coal. The B. & O. R. R. is near; both fuel and labor are plentiful. The place is favorable for location and operation of a plant. The clay is undeveloped and unutilized. The sample shows a conchoidal fracture; is olive green, very hard, has a slight amount of iron, and poor plasticity.

The data obtained indicate that this is a No. 1 flint fire clay which could be used successfully for the production of refractories.

Sample No. 14. Somerset County, Quemahoning Township: a shaly clay owned by J. M. Lambert, Coleman, Pa. It was obtained along the Johnstown and Rockwood Branch of the B. & O. R. R. about halfway between the towns of Coleman and Kimmelton at the No. 2 mine of the Olive Coal Co. The clay is of smooth texture, with rough and uneven fracture; it is 7 feet thick, gray, unoxidized, has no surface stain, and is soft throughout the bed. It underlies the Lower Freeport coal throughout the county. The B. & O. R. R. is near; both fuel and labor are plentiful. The place is favorable

for location and operation of a plant. The clay is undeveloped and unutilized. The sample shows a conchoidal fracture; is gray, soft, contains a trace of iron, and has very good plasticity.

The data obtained indicate that this clay has good burning properties. It could probably be successfully used for the production of paving brick, building brick or tile. It is not sufficiently refractory to be of much value as a fire brick material.

Sample No. 15. A cyanite obtained in Delaware County, owned by George Longcor, Marcus Hook, Pa. It is undeveloped and unutilized. The sample shows a splintery fracture; is silvery gray in color, very hard, has no impurities and has poor plasticity.

The data obtained indicate that this cyanite might represent a deposit which is likely to be in demand in the near future. It seems likely that the refractory industries will use large quantities of this type of material as soon as research work now under way shows how to utilize it in a commercial way.

Sample No. 16. Somerset County, Quemahoning Township: a clay owned by Jos. Birkeypile, Kantner, Pa. It was obtained from the mine of the Hillcrest Smokeless Coal Co. along the Johnstown and Rockwood Branch of the B. &. O. R. R. approximately 2 miles northeast of Stoyestown. It is fine grained and slightly gritty, 8 feet thick, light to dark gray, unoxidized, and has no surface stain. It grades from a thin broken bed of soft clay at the top to siderite at the bottom. The clay underlies the Upper Freeport coal. A railroad runs near the property; fuel is plentiful and the labor supply is good. The clay is undeveloped and unutilized. The sample shows a conchoidal fracture; is lead gray, medium hard, contains a medium amount of iron, and has very good plasticity.

The data obtained indicate that this clay has no economic value. It could not be successfully burned to a good product.

Sample No. 17. Somerset County, Quemahoning Township: Same owner and locality as No. 16. A hard and tough shale with rough and uneven fracture; it is 3 feet thick, dark gray, unoxidized and flinty, showing a fine grain throughout. It underlies the Lower Freeport coal. The clay is undeveloped and unutilized. The sample shows a conchoidal fracture; is very hard, has a trace of iron, and short plasticity.

The data obtained indicate that this is a shale which has been mistaken for a fire clay. It has very little economic value.

Sample No. 18. Somerset County, Elk Lick Township: a shaly clay owned by C. K. Bowman & Co., Boynton, Pa. It was obtained from the northwestern side of a ridge in the company's mine 1 mile north of Boynton. The clay extends 16 feet above the floor of the mine. The mine is in the Pittsburgh coal but the shale is undeveloped and unutilized. The sample shows a conchoidal fracture; is blue gray, very hard, has trace of iron, and short plasticity.

The data obtained indicate that this shale is similar to No. 17. It has little value.

Sample No. 19. Somerset County, Summit Township: a plastic clay owned by R. H. Whitford, Meyersdale, Pa. The plant at Keystone on the B. & O. R. R. 2 miles southeast of Meyersdale, where the sample was obtained, was idle in 1925. The sample shows an earthy fracture, is light gray, soft, and has good plasticity.

The data obtained indicate that this is a plastic clay of no value. Its short firing range, indicated by the porosity curves, makes it a difficult clay to burn commercially. The clay is thought to be at the Mercer horizon in the Pottsville group.

Sample No. 20. Somerset County, Summit Township: a plastic clay owned by the Consolidation Coal Co. It was obtained in a mine at Shaw Mines, 2 miles southwest of Meyersdale. The clay is in evenly stratified layers 3 to 6 inches thick with a total thickness of 15 inches. It is tough, dark gray, unoxidized, has no surface stain, and is of fine grain texture throughout. It lies on top of the Pittsburgh coal bed. This deposit is too small and not thick enough to work. The clay is undeveloped and unutilized. The sample shows a conchoidal fracture; is dark gray, very hard, and has very good plasticity.

The data obtained indicate that this is a fair quality No. 3 fire clay. It could be used for the production of paving brick, face brick or tile.

Sample No. 21. Somerset County: a flint clay owned by the Keystone Fire Brick Co., Meyersdale, Pa. It was obtained 2 miles southeast of Meyersdale at Keystone Junction on the Pittsburgh Branch of the B. & O. R. R. The clay underlies 450 acres. The thickness of the clay is about 8 feet; one-third of the deposit is flint clay nodules uniformly distributed throughout the whole bed. The clay is drab, unoxidized, and has no surface stain. It underlies the Lower Mercer coal. The clay is developed underground by the room and pillar method and is handled in mine cars. The plant and mine have been operated for 18 years. The clay is used for the manufacture of refractory brick and special shapes. The

sample shows a conchoidal and splintery fracture; is gray, very hard, has a medium amount of iron, and poor plasticity.

The data obtained indicate that this clay is a good quality No. 1 fire clay.

Sample No. 22. Somerset County, Fairhope Township: a flint clay owned by the Savage Brick Co., Williams, Pa. It was obtained from the Williams Brick Works, 4 miles west of Hyndman, on the B. & O. R. R. The clay underlies 1500 acres. It is blocky, very hard, and of smooth texture: it is 5 to 12 feet thick, drab, slightly oxidized, and has some surface stain. It is homogeneous, under lain by 2 feet of soft clay. The clay lies between the Sharon coal and conglomerate. The plant is not operated at present. The clay was developed underground by the room and pillar method: handled with mine cars; and manufactured into fire brick and shapes. The sample shows a conchoidal fracture; is gray, very hard, contains a medium amount of iron, and has poor plasticity.

The data obtained indicate that this clay is good quality No. 1 fire clay.

Sample No. 23. Somerset County, Southampton Township: owner and locality same as No. 22. A soft, plastic clay of smooth texture; it is 2 feet thick and lies on flint clay. It is drab, slightly oxidized, has some surface stain, and is homogeneous. It lies between the Sharon coal and conglomerate. The plant is not being operated at present. The clay was developed underground by the room and pillar method; handled by mine cars; and utilized for binder and fire brick cement. The sample submitted shows an earthy and splintery fracture; is light gray, soft, has some iron, and very good plasticity.

The data obtained indicate that this clay is fair quality No. 3 plastic clay. Could be used for refractories.

Sample No. 24. Somerset County, Fairhope Township: a plastic clay owned by Lewis M. Neld, Fairhope, Pa. It was obtained from a deposit underlying the thin Sharon coal at Fairhope, on the Pittsburgh Division of the B. & O. R. R., a short distance north of Williams, Pa. The clay is 20 feet thick, 17 feet being soft and 3 feet flint; it is light gray, oxidized, and has a slight surface stain; the upper part is soft and the lower hard. The country is very hilly. A railroad is nearby; both fuel and labor are plentiful. The plant has been idle a number of years. The clay was obtained by mining. The sample shows an earthy fracture; is light gray, soft, has a medium amount of iron, and good plasticity.

The data obtained indicate that this is poor quality fire clay. Its erratic burning behavior and low fusion render it practically useless.

Sample No. 25. Somerset County, Fairhope Township: Same owner and locality as No. 24. A plastic clay 6 to 15 feet thick, of unknown horizontal extent, accompanying a split in the Upper Mercer coal. The clay was obtained by mining. The sample shows an earthy fracture; is light gray, soft, contains a trace of iron, and has very good plasticity.

The data obtained indicate that this is No. 3 plastic clay which might be used for refractories, paving brick or tile.

Sample No. 26. Fayette County, Bullskin Township: a flint clay owned by the Joseph Soisson Fire Brick Co., Connellsville, Pa. It was obtained 4½ miles northeast of Connellsville. The clay is of fine and smooth texture and is splintery. The bed is 11 feet thick, dark drab, oxidized, has a slight surface stain, and is composed of 2 feet of soft clay resting on 9 feet of flint clay. It lies above the Upper Freeport coal horizon. The sample shows a splintery fracture; it has a gray-olive tint, is very hard, contains a trace of iron, and has poor plasticity.

The data obtained indicate that this is a No. 2 flint fire clay. Its fusion point and burning curves lead one to question the accuracy of the chemical analysis given in the tables.

Sample No. 27. Fayette County, Connellsville Township: a semi-flint clay owned by the Joseph Soisson Fire Brick Co., Connellsville, Pa. It was obtained in the town of Gibson or South Connellsville on the main line of the B. & O. R. R. and the Youghiogheny River. The bed is 11 feet thick, 7 feet being soft clay and 4 feet flint clay; the sample is taken from the 7 feet of plastic clay over the flint clay. It is medium gray, unoxidized, has no surface stain, and is a homogeneous mass. The clay becomes plastic when exposed to the weather. It lies between the Mahoning sandstone and Brush Creek coal. The country is hilly, and the clay bed outcrops along a deep river gorge. The B. & O. R. R. is present; fuel is available and the labor supply is good. The clay is obtained by stripping, handled by steam shovels and cars, and manufactured into common building brick, coke oven brick and low refractory brick. The sample shows a splintery fracture, is light gray, medium hard, contains a trace of iron, and has short plasticity.

The data obtained indicate that this is a low grade fire clay having burning properties which render it capable of being satisfactorily used for building brick and low grade refractories.

Sample No. 28. Fayette County: same locality and owner as No. 27, same method of mining and same use. A flint clay. The sample was taken from the 4 feet of flint clay underlying the soft clay No. 27. The clay is drab, unoxidized, has no surface stain, and is homogeneous. It lies between the Mahoning sandstone and the Brush Creek coal. The sample shows a conchoidal and splintery fracture; is light blue-gray, very hard, has a medium amount of iron, and poor (sandy) plasticity.

The data obtained indicate that this is a No. 2 flint fire clay.

Sample No. 29. Fayette County, Connellsville Township: a plastic clay owned by the Joseph Soisson Fire Brick Co., Connellsville, Pa. It was obtained in South Connellsville, a short distance north and approximately ½ mile east of the terminus of the street car line, near the base of Chestnut Ridge. The clay underlies the Upper Freeport coal. It is plastic when exposed to weather; it is 10 feet thick, unoxidized, and has a slight surface stain. It is a homogeneous mass. There are no railroads near; fuel and labor are plentiful. The clay is mined in conjunction with the coal, handled by wagons, and manufactured into building brick, coke oven brick and refractory brick. The sample shows a splintery fracture, is light gray, medium hard, contains a trace of iron, and has very good plasticity.

The data obtained indicate that this is a No. 1 plastic clay capable of producing No. 1 fire brick.

Sample No. 30. Fayette County, Dunbar Township: a plastic clay obtained from an outcrop along the Western Maryland R. R. 2 miles southwest of Connellsville, Pa. It is in the Conemaugh group directly under the upper bench of the Mahoning sandstone. The clay is hard and tough, showing slaking properties; is 3 feet thick, oxidized, has some iron, and is homogeneous. The deposit lies at the base of a cliff so close to the Western Maryland tracks that development would be difficult. Both fuel and labor are available. The clay is undeveloped and unutilized. The sample shows a splintery fracture, is medium gray, medium hard, and has good plasticity.

The data obtained indicate that this is a No. 3 fire clay, very good burning properties and could be used for the production of refractories.

Sample No. 31. Fayette County, Dunbar Township: a flint clay owned by the Eureka Fire Brick Co., Mount Braddock, Pa. It was obtained 7 miles southwest of the town of Connellsville on the main line of the B & O. R. R. on the northwest slope of Chestnut

Ridge. The clay is in the Conemaugh group under the Brush Creek coal, and underlies 50 acres. It is hard, slightly splintery and blocky. The clay is 6 feet thick, homogeneous, drab, unoxidized, and has a slight surface stain. The country is hilly. A railroad is near; fuel and labor are available. The clay is obtained by mining; handled by inclined plane and cars to plant; and manufactured into refractory brick. The sample shows a splintery fracture, is blue gray, very hard, has a slight amount of iron, and poor (sandy) plasticity.

The data obtained indicate that this is a No. 2 fire clay with good burning properties.

Sample No. 32. Fayette County, same owner, locality, method of mining and use as No. 31. This is a plastic and flint clay mixture. The clay is hard and tough, 4 feet thick, gray, unoxidized, and the lower half is of better quality than the upper half. The sample shows an earthy and splintery fracture, is medium gray, soft, contains a slight amount of iron, and has very good plasticity.

The data obtained indicate that this is a No. 3 fire clay with good burning properties.

Sample No. 33. Fayette County, Georges Township: a plastic clay owned by the Fayette Fire Brick Co., Uniontown, Pa. It was obtained 6 miles south of Uniontown, at Fairchance on the Connellsville Branch of the B. & O. R. R., northwest slope of Chestnut Ridge. The extent of the clay has been proved for 350 acres. It is in the Pottsville group under the Sharon coal. The clay is hard, tough and massive, it is 10 feet thick, drab, unoxidized, has no surface stain, and is a solid, homogeneous mass. The country is mountainous. The B. & O. R. R. is near; fuel and labor available. The clay is obtained by stripping; handled by steam shovels and tram cars; and is manufactured into different colored tapestry building brick, coke oven and paving brick. The sample shows a splintery fracture; is light gray, medium hard, has a medium amount of iron, and very good plasticity.

The data obtained indicate that this is a fire clay having excellent burning properties. The regular, uniform rates of shrinkage, and porosity change shown by the curves for this clay are typical of many clays successfully used for brick, etc.

Sample No. 34. Westmoreland County, Hamphill Township: a semi-flint clay owned by the Westmoreland Fire Brick Co., Pittsburgh, Pa. It was obtained one mile west of Hunkers on a branch line of the Pennsylvania R. R. The clay is under the Upper Free-

port coal and separated from it by 3 feet of limestone and 10 feet of sandstone. It underlies 500 acres. The clay is very hard, hackly and fine grained; it is 8 feet thick, 4 feet flint and 4 feet plastic; light drab in color, unoxidized and stratified in layers of 3 to 6 inches. The country is hilly. The P. R. R. is near; fuel and labor are available. The clay is obtained by mining; handled by mine motors and cars; and manufactured into fire brick. The sample shows a conchoidal fracture; is medium gray, hard, contains a very slight trace of iron, and has short plasticity.

The data obtained indicate that this is a medium quality No. 3 fire clay.

Sample No. 35. Westmoreland County, same owner, locality, and use as No. 34. The clay in the bed is fine grained with uneven fracture; brownish in color, unoxidized, has no surface stain, and is homogeneous. The sample shows a conchoidal and splintery fracture; is steel gray, very hard, has a medium amount of carbon and poor (sandy) plasticity.

The data obtained indicate that this is a good quality No. 2 fire clay.

Sample No. 36. Westmoreland County, Derry Township: a plastic clay owned by the Joseph Soisson Fire Brick Co., Connellsville, Pa. It was obtained from the Kingston Brick Works at Kingston on the Ligonier Valley R. R. and the Loyalhanna River, on the northwest slope of Chestnut Ridge. The clay is 8 feet thick; fine grained, smooth and nodular, gray to drab, unoxidized, has a slight surface stain, and is homogeneous. The clay is in the Pottsville group, and separated from the Sharon coal by 8 feet of shale. The country is mountainous. Fuel and labor are available. The clay is obtained by stripping and is manufactured into coke oven brick, low refractory brick and paving brick. The sample shows a splintery fracture; is light gray, soft, has a medium amount of iron, and very good plasticity.

The data obtained indicate that this clay has good working and burning properties. Its fusion point is too low for high grade refractories.

Sample No. 37. Westmoreland County, Derry Township: same owner, locality, and uses as No. 36, and part of the same bed. The sample submitted shows a splintery fracture; is medium gray, hard, has a slight amount of iron, and very good plasticity.

The data obtained indicate that this clay is similar to No. 36. Its hard, stony character is the only feature wherein it can be distinguished from No. 36.

Sample No. 38. Indiana County, West Wheatfield Township: a plastic clay owned by the Garfield Fire Brick Co., Robinson, Pa. It was obtained in the mines and brick yard ½ mile west of Robinson on the Conemaugh Division of the Pennsylvania R. R. on the bank of Conemaugh River. The clay underlies the Upper Mercer coal in the Pottsville group, in an area of 2,000 acres. The clay is soft, solid, tough, and coarse grained; it is 8 feet thick, gray, unoxidized, has no surface stain, and is a homogeneous mass. Fuel and labor are available. The clay is obtained by mining, handled by mine cars, and manufactured into fire brick. The sample shows a conchoidal fracture; is gray, soft, has a slight amount of iron and very good plasticity.

The data obtained indicate that this is a good quality No. 2 fire clay. Its shrinkage curve is very good. The sudden drop in porosity occuring at 1300° C. is difficult to explain.

Sample No. 39. Indiana County, West Wheatfield township: a semi-flint clay owned by the Joseph Soisson Fire Brick Co., Connellsville, Pa. It was obtained from the Garfield plant and mines on the Conemaugh Division of the Pennsylvania R. R. on the bank of Conemaugh River, ½ mile west of Robinson. The clay underlies the Lower Kittanning coal in the Allegheny group. The clay is 12½ feet thick, the sample being taken from the lower 6½ feet of the bed; it is gray, unoxidized, has no surface stain and is homogeneous in benches. The country is hilly, being along a river valley. Fuel and labor are available. The clay is obtained by mining, handled by mine cars, and manufactured into common brick. The sample submitted shows a splintery fracture; is light gray, medium hard, contains slight amounts of iron and sulphur, and has very good plasticity.

The data obtained indicate that this clay has good burning properties but is not sufficiently refractory for fire brick.

Sample No. 40. Indiana County, West Wheatfield Township: same owner and location, bed and use as No. 38. The clay is hard, tough and coarse, unoxidized, gray, and has no surface stain. It is a stratified homogeneous mass, and is the bottom 8 feet of a 17-foot bed underlying the Upper Mercer coal. The sample shows a conchoidal fracture; is dark gray, soft, contains a very slight amount of iron, and has very good plasticity.

The data obtained indicate that this clay is a high grade No. 1 fire clay.

Sample No. 41. Indiana County, West Wheatfield Township: a plastic clay owned by the Joseph Soisson Fire Brick Co., Connells-

ville, Pa. It was obtained on the bank of Conemaugh River near Robinson, from the same bed as samples Nos. 38 and 40. Here just under the Upper Mercer coal is 5 feet of plastic clay underlain by 4 feet of sandy shale and under this 8 feet of plastic clay from which Sample No. 40 was obtained. Sample No. 41 was taken from the bottom 4 feet of the deposit. The clay is unoxidized, has no surface stain and is homogeneous. The clay is obtained by mining; handled by mine cars; and manufactured into a high grade of refractory brick. The sample shows a splintery fracture; is dark gray, very hard, has a slight amount of iron and very good plasticity.

The data obtained indicate that this is a fair quality No. 3 fire clay. It overfires at about 1300° C.

Sample No. 42. Indiana County, West Wheatfield Township: a flint clay owned by the Joseph Soisson Fire Brick Co., Connellsville, Pa. It was obtained on the east side of Conemaugh River near Robinson. The bed extends for 400 acres, and is separated from the Upper Freeport coal by 11 feet of shale, sandstone and limestone. The clay is hard, bedded, jointed and hackly; it is 5 feet thick, black, unoxidized, has some surface stains, and contains some impure material in bedding and joint planes. The country is hilly; the Pennsylvania R. R. is near; fuel and labor are available. The clay is obtained by mining, handled by mine cars, and manufactured into refractory brick. The sample shows a splintery fracture, is dark gray, very hard, contains a medium amount of iron and has poor (sandy) plasticity.

The data obtained indicates that this is good quality No. 2 flint clay.

Sample No. 43. Indiana County, West Wheatfield Township: same owner and location as No. 42. The clay which underlies the Lower Kittanning coal, is 12 feet 6 inches thick. The sample was taken from a middle bench 4 feet thick; it is unoxidized, has no surface stain and is homogeneous. The clay is obtained by mining, handled by mine cars and manufactured into common brick. The sample shows an earthy fracture; is medium gray, soft, contains slight amounts of sulphur and iron, and has very good plasticity.

The data obtained indicate that this is a No. 3 fire clay. It has rather erratic porosity change and overfires at about 1300° C.

Sample No. 44. Indiana County, West Wheatfield Township: same place, owner, bed, and use as No. 43. A plastic clay representing the top 2 feet of a 12½ foot bed just under the Lower

Kittanning coal. The clay is homogeneous, unoxidized and contains $FeSO_4$. The sample shows an earthy fracture, is medium gray, soft, contains a medium amount of sulphur and has good plasticity.

The data obtained indicate that this is a No. 3 fire clay having good burning properties and low drying shrinkage.

Sample No. 45. Clinton County, Bald Eagle Township: a flint clay owned by the Stowe-Fuller Refractories Co., Lock Haven, Pa. It was obtained at the Goose Hill mine along Scootack Creek within about 2 miles east of the Wilson Hill mine. The bed underlies the Upper Kittanning coal in 1696 acres. The clay is tough, slickensided, and of coarse texture; it is 4 feet thick, homogeneous, light drab, unoxidized and has a slight surface stain. The country is hilly and rough. The Pennsylvania R. R. traverses the property; fuel and labor are available. The clay is obtained by mining, handled by mine cars, and manufactured into common and refractory brick. The sample shows a splintery fracture, is dark gray, very hard, has a slight amount of iron and poor (sandy) plasticity.

The data obtained indicate that this is high grade flint fire clay. It can be used in the production of No. 1 fire brick.

Sample No. 46. Clinton County, Bald Eagle Township: a plastic clay owned by the Stowe-Fuller Refractories Co., Lock Haven, Pa. It was obtained from the Wilson Hill Mine 3 miles from Birds Run Station, 10 miles west of Lock Haven along the Scootack branch of the Pennsylvania Railroad. The bed underlies the Brookville coal in a property of 1696 acres. The clay is hard, tough, blocky, and fine grained, light drab, and has some surface stain. It is a 4-foot bed consisting of 1 foot of plastic and 3 feet of flint clay. The sample tested represents the plastic clay. The Pennsylvania R. R. runs through the property; fuel and labor are available. The clay is obtained by mining, handled by mine cars, and manufactured into common brick and refractory brick. The sample shows an earthy fracture, is medium gray, soft, has a medium amount of iron, and good plasticity.

The data obtained indicate that this is a No. 3 fire clay. It overfires at about 1350° C.

Sample No. 47. Clinton County, Colebrook, Woodward and Gallagher Townships: a flint clay owned by the Queens Run Refractories Co., Lock Haven, Pa. The property of 4,600 acres underlain by this clay is 6 miles northwest of Lock Haven on the P. & E. division of the Pennsylvania R. R. along Susquehanna River. The clay underlies the Brookville coal at the base of the Allegheny

group. The clay is hard and tough, with rough texture; it is light gray, unoxidixed, has some surface stain, and its bottom bench is a homogeneous mass. The bed is in two 3-foot benches, the upper one flint clay and the bottom bench plastic clay. This sample represents the top bench. The country is rough and mountainous, the mines being approximately 600 feet above the railroad on the mountain side. Both fuel and labor are available. The clay is obtained by mining; handled by dinky railroad and mine cars; and manufactured into all kinds of refractory brick, special shapes, etc. The sample shows a splintery fracture; is medium gray, very hard, has a slight amount of iron, and short plasticity.

The data obtained indicate that this is a high grade No. 1 flint fire clay.

Sample No. 48. Clinton County: same owner, place, bed and use as No. 47. The sample represents 3 feet of plastic clay underlying No. 47. It shows an earthy and conchoidal fracture, is light gray, medium hard, contains a medium amount of iron, and has good plasticity.

The data obtained indicate that this is a fine quality No. 1 plastic fire clay. The shrinkage and porosity curves of this clay show remarkable uniformity.

Sample No. 49. Clinton County, Beech Creek Township: a flint clay owned by the Harbison-Walker Refractories Co., Pittsburgh, Pa. This clay underlies the Brookville coal in a property of 250 acres and is mined 2 miles northeast of Monument, which is 13 miles west of Lock Haven. The mine is 500 feet above Monument and reached by a dinky railroad 3 miles long. The clay is blocky, fine grained, and smooth; it is 7 feet thick with 4 feet of block clay; dark gray, unoxidized, has a slight surface stain, and is a solid homogeneous mass. The country is mountainous. The N. Y C. passes through Monument. A good supply of fuel is available and labor is at hand. The clay is obtained by mining; handled by inclined plane and dinky railroad; and manufactured into all kinds of refractory brick. The sample shows a splintery fracture; is dark gray, very hard, has traces of carbon and iron, and has short plasticity.

The data obtained indicate that this is a high grade No. 1 fire clay. The burning curves of the clay show a very gradual shrinkage, starting at about 1100° C.

Sample No. 50. Clinton County, Beech Creek Township: a plastic clay owned by the Harbison-Walker Refractories Co., Pittsburgh, Pa. This clay underlies the Brookville coal and is mined ¾ mile

north of Monument 500 feet above the creek, in a steep hillside. It is utilized at the brick plant at Monument. The bed extends for 250 acres. The clay is fine grained and smooth; is 6 feet thick, unoxidized, has a slight surface stain, and is a solid homogeneous mass. The country is mountainous. The N. Y. C. passes through Monument. Both fuel and labor are good. The clay is obtained by mining; handled by friction plane, dinky railroad and mine cars; and is manufactured into all kinds of refractory brick. The sample shows an earthy and conchoidal fracture; is medium gray, soft and has very good plasticity.

The data obtained indicate that this is a good quality No. 2 fire clay. The burning curves of this clay indicate excellent behavior in firing.

Sample No. 51. Clearfield County, Decatur Township: a plastic clay owned by the General Refractories Co. It was obtained at the Reed mine 1½ miles west of West Decatur P. O. and the company's Blue Ball plant on the N. Y. C. R. R., approximately 6 miles from Philipsburg. The bed underlies the Clarion coal near the base of the Allegheny group in property of 100 acres. The clay is hard, tough, coarse and granular; it is 6 feet thick, this sample being taken from the upper 3 feet, the bottom 3 feet being quite sandy. The clay is light gray, unoxidized, has an iron stain, and is homogeneous. The N. Y. C. R. R. is present; both fuel and labor are available. The clay is obtained by mining; handled by mine cars; and manufactured into refractory brick. The sample shows an earthy fracture, is soft, and has very good plasticity.

The data obtained indicate that this is a No. 2 fire clay, swelling at about 1050° C. It overfires at about 1350° C.

Sample No. 52. Clearfield County, Decatur Township: a semi-flint clay owned by the General Refractories Co. It was obtained at the McClaren mines approximately 4½ miles west of the Blue Ball plant and 3 miles west of the Reed soft clay mine. The clay extends for 50 acres. The clay is massive, blocky, fine grained, and hackley; it is 8 feet thick, blackish drab, unoxidized, and has no surface stain. There are 18 inches of soft clay on top of the flint clay. The N. Y. C. R. R. is present; both fuel and labor are available. The clay is obtained by mining; handled by mine cars; and manufactured into refractory brick. The sample shows a splintery fracture; is dark gray, hard, has a slight amount of iron, and poor (sandy) plasticity.

The data obtained indicate that this is a good quality No. 1 fire clay. The regularity of the burning curves indicates good burning properties.

Sample No. 53. Clearfield County, Decatur Township: a flint nodular clay owned by the General Refractories Co. It was obtained about 4½ miles west of Blue Ball and ½ mile south of the McClaren No. 10 mine. The bed is in an eroded dome and is practically worked out. The bed is in the Pottsville group and is separated from the Mercer coal by approximately 3 feet of black shale. The clay is 4 to 5 feet thick, is green and brown, unoxidized, has no surface stain, and has brown or burned nodules distributed through the green nodules. The country is a dome-like structure with clay outcropping on all sides. The N. Y. C. R. R. is present: both fuel and labor supply are good. The clay is obtained by mining and stripping; handled by steam shovels and mine cars; and manufactured into the best grades of refractory brick and shapes. The sample shows a splintery fracture; is dark gray, very hard, has a medium amount of iron, and poor (sandy) plasticity.

The data obtained indicate that this is a fine quality No. 1 fire clay.

Sample No. 54 Clearfield County, Bradford Township: a plastic clay owned by the General Refractories Co. The clay underlies 10 inches of Clarion (dirty) coal in a 200 acre tract 1 mile northeast of Woodland, and 8 miles from the company's Blue Ball plant on the N. Y. C. R. R. The sample was obtained from the Walker mine. The clay in the bed is slickensided, and has a rough and burley fracture; it is 9 feet thick, light gray, unoxidized, has no surface stain, and is a solid homogeneous mass. The bed lies on the northwest slope of a local anticline. The N. Y. C. R. R. and Pennsylvania R. R. are near; both fuel and labor are available. The clay is obtained by mining, development having been started in 1925; handled by mine cars; and manufactured into refractory brick. The sample shows a conchoidal fracture, is medium gray, soft, and has very good plasticity.

The data obtained indicate that this is a fair quality No. 2 fire clay. It overfires between 1350 and 1400° C.

Sample No. 55. Centre County, Rush Township: a semi-flint clay owned by the General Refractories Co. The sample was obtained from the Forge Run mine 12 miles east of the Blue Ball plant on the head of Sixmile Run about 8 miles east of Philipsburg. The clay, which is in the Pottsville group, under the Mercer coal, underlies 3,000 acres. It is fine grained and smooth: 4 feet thick, dark gray to drab, unoxidized, and is a solid, slightly blocky mass. The country is mountainous. A tram railway connects the mine with the N. Y. C. R. R. Fuel and labor are plentiful. The clay is obtained by mining, handled by mine cars, and manufactured into

refractory brick. The sample shows a splintery fracture, is lead gray, medium hard, has a slight amount of iron and short plasticity.

The data obtained indicate that this is a good quality No. 2 fire clay.

Sample No. 56. Centre County, Rush Township: a semi-flint clay owned by the General Refractories Co. It was obtained 3½ miles east of Winburne and approximately 1 mile north of Viaduct on the N. Y. C. R. R. in the steep bluff of Moshannon Creek. The bed is in the Pottsville sandstone and overlain by black shale of the Lower Mercer horizon. The clay is fine grained, very hard and hackly, dark gray, unoxidized, and has no surface stain; it is 6 feet thick, composed of 4 feet of flint overlying 2 feet of burley clay. Topographically the country is mountainous. The N. Y. C. R. R. is near; both fuel and labor supply are good. The clay is obtained by mining, handled by mine cars, and manufactured into high grade No. 1 refractory brick. The sample represents the 4 feet of flint clay, shows a splintery fracture, is medium gray, hard, contains a slight amount of iron, and has short plasticity.

The data obtained indicate that this is a high grade No. 1 fire clay. The slow and uniform shrinkage of this clay indicates fine burning properties.

Sample No. 57. Centre County, Rush Township: same owner, place, bed, and use as No. 56. The sample represents the lower 2 or 3 feet of plastic burly clay under No. 56. The sample shows a conchoidal fracture, is light gray, soft, contains a medium amount of iron and has good plasticity.

The data obtained indicate that this is a high grade No. 1 fire clay. It has rather high burning shrinkage and begins to overfire at about 1400° C.

Sample No. 58. Clearfield County, Karthaus Township: a plastic clay owned by the General Refractories Co., Blue Ball, Pa. It was obtained in the Cochran soft clay mine at Karthaus, on the N. Y. C. R. R. The clay is light gray and has no surface stain. Its geologic position was not determined. The clay is obtained by mining and is manufactured into refractory brick. The sample shows an earthy fracture, is soft and has very good plasticity.

The data obtained show that this is a fair quality No. 3 fire clay. It has good burning properties and begins to overfire at about 1350° C.

Sample No. 59. Luzerne County: a semi-flint clay owned by L. H. Atherholt, Wilkes-Barre, Pa., and mined ½ mile west of Forty

Fort between the Ross and Red Ash beds in the Allegheny group, and underlies the Ross coal. The clay is 12 feet thick and dark slate in color. The sample shows a splintery fracture, is medium hard, has very good plasticity.

The data obtained show that this is a low grade clay. It can hardly be properly classed as a fire clay. Its burning curves would indicate it is a shale which overburns at 1300° C.

Sample No. 60. Clearfield County, Greenwood Township: a shale owned by Robert L. Derrick, Clearfield, Pa. It was obtained on the Derrick estate ½ mile from Bells Landing, underlying the Pennsylvania Coal & Clay Corp. mine No. 2 in the Lower Freeport or "D" coal. The shale is soft with a conchoidal fracture; it is 4 feet thick, medium gray, slightly oxidized, has a medium iron surface stain, and is a homogeneous mass. The country is hilly. The N. Y. C. R. R. runs within ½ mile of the mine opening; both fuel and labor supply are good. The shale is not developed. The sample is medium hard, contains a medium amount of iron, and has very good plasticity.

The data obtained indicate that this shale has no economic value.

Sample No. 61. Bedford County, Broad Top Township: a semi-flint clay owned by the Kay Coal Mining Co., Everett, Pa. It was obtained 1¾ miles east of the Raystown Branch of the Juniata River on Longs Run near the village of Langdondale in the Broad Top coal field. The clay is about 250 feet above the Kelly or C' coal bed in the Conemaugh group and underlies 22 inches of coal, which is probably the Mosquito Hollow, correlating with Bakerstown coal. The clay is hard and splintery; it is 3 feet thick, medium gray in color, unoxidized, has a slight surface stain and is homogeneous. It is not developed. The sample shows a splintery fracture, is very hard, has a slight amount of iron, and short plasticity.

The data obtained indicate that this is a very low grade No. 3 fire clay. Its burning curves up to 1250° C. are quite satisfactory but at this point the clay suddenly fuses.

Sample No. 62. Wyoming County, Meshoppen Township: a shale owned by Lewis B. Carter, on Carter's farm, Skinners Eddy, Pa. It was obtained 15 miles northwest of Tunkhannock at Black Walnut along Susquehanna River. The shale is 30 feet thick, tan in color, and in an earthy, homogeneous mass. Its geologic position was not determined and the deposit is not developed. The sample is soft and has very good plasticity.

The data obtained indicate that this is a shale which might be used for the production of building brick or tile. It has no value as a refractory.

Sample No. 63. Clearfield County: a plastic clay owned by the Harbison-Walker Refractories Co., Pittsburgh, Pa. It was obtained 3 miles southeast of Clearfield along the main road to Philipsburg. Geologically the bed belongs to the Pottsville formation. The Pennsylvania R. R. and N. Y. C. R. R. are present; both fuel and labor supply are good. The clay is obtained by mining, handled by mine cars, and manufactured into fire brick and refractory material. The sample shows an earthy and conchoidal fracture; is medium gray, soft, and has very good plasticity.

The data obtained indicate that this is a fine quality No. 1 plastic fire clay.

Sample No. 64. Clearfield County, Penn Township: a flint nodular clay owned by the Harbison-Walker Refractories Co., Pittsburgh, Pa. It was obtained 1 mile southeast of Grampian along the Pennsylvania R. R. The bed is in the Allegheny group. Both fuel and labor supply are good. The clay is obtained by mining, handled by mine cars, and manufactured into fire brick and refractory material. The sample shows a splintery fracture, is medium gray, very hard, contains a slight amount of iron, and has poor (sandy) plasticity.

The data obtained indicate that this is a high grade No. 1 fire clay. It has a slow, regular shrinkage beginning at 1050° C. and continuing up to 1400°.

Sample No. 65. Wyoming County, Falls Township: a red clay owned by C. A. Van Tuyl, Falls, Pa. The sample shows an earthy fracture, is light gray, soft, has a large amount of iron, and very good plasticity.

The data obtained indicates that this is a red burning clay having very good burning and drying properties. It overfires at 1300° C. This clay could be successfully used for the production of building brick or tile. It would make a good drain tile.

Sample No. 66. Wyoming County, Falls Township: a red clay owned by C. A. Van Tuyl, Falls, Pa. The sample shows a splintery fracture, is green gray, medium hard, has a large amount of iron, and very good plasticity.

The data obtained indicate that this is a red burning clay having no value. It could not be successfully burned commercially.

Sample No. 67. Centre County, Rush Township: a plastic clay owned by the Morning Star & Schnars Coal Co., Philipsburg, Pa. It was obtained from Schnars coal mine on a branch of the N. Y.

C. R. R. 3 miles northeast of Philipsburg, between North Run and Barlow Hollow. The clay bed is 12 feet thick, light gray, and is composed of 2 feet of flint clay overlying 10 feet of soft clay. The clay is in the Pottsville group, and underlies 3 feet 10 inches of Brookville coal. The sample shows an earthy and splintery fracture; is light gray, slightly hard, has a slight amount of iron, and good plasticity.

The data obtained indicate that this is a fair quality No. 3 fire clay. It overfires at about 1300° C.

Sample No. 68. Tioga County, Delmar Township; a red shale owned by Fred A. Graham, Wellsboro, Pa. It was obtained from an outcrop at the base of a hill 7 miles south of Wellsboro and ¾ mile from Morris Creek. The shale is 5 feet thick and light gray. It is in the Pottsville group. The sample shows a splintery fracture, is light gray, medium hard, contains a medium amount of iron, and has good plasticity.

The data obtained indicate that this is a red burning shale of doubtful economic value. It might be used for the production of building brick or tile.

Sample No. 69. Clinton County, Noyes Township: a flint clay owned by Geo. H. Smith, Westport, Pa. It was obtained on Shintown Run 3 miles west of Renovo. The clay is hard, splintery and conchoidal; it is 3 to 6 feet thick, dark gray, unoxidized, and homogeneous. The bed is in the Allegheny group, and underlies the Brookville coal. The country is hilly. The Pennsylvania Railroad passes through Shintown. The clay is not developed. The sample is very hard, and has poor (sandy) plasticity.

The data obtained indicate that this is a good quality No. 1 fire clay.

Sample No. 70. Clearfield County, Greenwood Township: a plastic clay owned by D. F. Bell, Bells Landing, Pa. It was obtained 1 mile due north of Bells Landing along Bell Run. The clay is 10 feet thick, 6 feet being plastic; it is light gray, has a medium amount of iron stain on the surface, and is an earthy, homogeneous mass. The bed underlies the Lower Kittanning coal. The country is hilly. The N. Y. C. R. R. is within 1 mile of the property; both fuel and labor are available. The clay is not developed. The sample shows an earthy fracture, is light gray, soft, contains a medium amount of iron, and has good plasticity.

The data obtained indicate that this is a fair quality No. 3 fire clay. It overfires at about 1300° C.

Sample No. 71. Clearfield County, Greenwood Township: same owner, place, and bed as No. 70. A flint clay that makes 4 feet of a 10-foot bed. The clay is hard, splintery and blocky. The sample submitted shows a conchoidal and splintery fracture; is steel gray, very hard, contains some iron, and has poor (sandy) plasticity.

The data obtained indicate that this is a rather poor quality No. 2 flint fire clay. It is high in free silica as compared with the general run of flint fire clays.

Sample No. 72. Jefferson County, Clover Township: a plastic clay owned by the Hanley Ceramics Co., Bradford, Pa. It was obtained at the mine openings north of Red Bank Creek near Summerville on the Pennsylvania R. R. The bed is 5 to 10 feet thick and lies 45 feet below the Vanport limestone. The sample was taken from the lower part of the bed. The clay is light gray, unoxidized, has an iron surface stain, and is homogeneous. The country is hilly. Both fuel and labor supply are good. The clay is obtained by mining, handled by mine cars, and manufactured at Summerville into fire brick, etc. The sample submitted shows a conchoidal fracture; is lead gray, medium hard, has a slight amount of iron, and very good plasticity.

The data obtained indicate that this is a No. 3 plastic fire clay. It can be used only for the production of building brick, tile or low grade refractories.

Sample No. 73. Jefferson County, Clove Township: same owner, place, bed and use as No. 72. A plastic clay from the upper part of the bed. The clay is dark gray, unoxidized, and homogeneous. The sample shows a conchoidal fracture; is dark gray, soft, and has very good plasticity.

The data obtained indicate that this clay is similar to No. 72 but more refractory. It could be used for the production of fire brick.

Sample No. 74. Clearfield County, Lawrence Township: a plastic clay owned by the Robinson Clay Products Co., Clearfield, Pa. It was obtained approximately 1 mile east of Clearfield in a hillside mine. The clay is 6 feet thick, dark gray, and underlies the Middle Kittanning coal. The Pennsylvania R. R. and N. Y. C. R. R. are present; both fuel and labor are plentiful. The clay is obtained by mining; handled by mine cars and aerial conveyor; and manufactured into sewer pipe. Development of this mine was started in 1923. The sample shows a conchoidal fracture; is dark gray,

soft, contains a slight amount of carbon, and has very good plasticity.

The data obtained indicate that this is a No. 3 plastic fire clay. Its burning properties are satisfactory up to 1300° C. Above that it overfires.

Sample No. 75. Huntingdon County, Porter Township: a white surface clay owned by G. I. Philips, Alexandria, Pa. It was obtained at the base of the Oriskany sandstone along the pike half way between Alexandria and Huntingdon. The clay is white and homogeneous. The clay is dug by steam shovel and is used for refractory purposes. The sample submitted shows an earthy fracture, being easily powdered; is white and has very good plasticity.

The data obtained indicate that this is a very siliceous clay, deriving its high fusion point from its high silica content. It has good burning properties and would probably be satisfactory as a cement for laying silica brick, but not as a refractory where a basic ash or slag is encountered.

Sample No. 76. Clearfield County, Bell Township: a plastic clay owned by the Madeira Hill Coal Mining Co., Philipsburg, Pa. It was obtained from a mine in the Lower Freeport or D coal 6 miles northwest of Mahaffey on the head of Clover Run. The clay, which underlies all the coal in the mine, is 5 feet thick, medium gray, and is composed of 4 feet of soft clay and 1 foot of harder clay. The country is a dissected plateau with narrow stream valleys. The Pennsylvania R. R. is near; both fuel and labor supply are good. The clay is not developed. The sample is medium gray, soft, and has good plasticity.

The data obtained indicate that this is a No. 3 fire clay. It overfires badly at about 1300° C.

Sample No. 77. Clearfield County, Bell Township: same owner, place, and bed as No. 76. A shale of undetermined thickness which underlies 4 feet of plastic clay, which in turn underlies the "D" or Lower Freeport coal. The shale is not developed. The sample shows a conchoidal fracture, is medium gray, soft, contains a slight amount of carbon, and has very good plasticity.

The data obtained indicate that this is a shale of doubtful economic value. It overfires badly at 1300° C.

Sample No. 78. Clearfield County, Greenwood Township: a red clay owned by the Good Coal & Clay Co., Patton, Pa. It was obtained from the bottom clay under the Lower Freeport coal one mile in the hills back of Bells Landing. The clay is 2 to 4 feet

thick; medium gray, has a slight iron and carbon stain, and is a soft homogeneous mass. The country is hilly. The N. Y. C. R. R. is present with coal mine sidetrack. The clay is obtained by mining, handled by mine cars and gravity plane to tipple, and shipped and manufactured into tile at the Patton works of the company. The sample shows a conchoidal fracture, and has very good plasticity.

The data obtained indicate that this is a red burning clay, which would be very difficult to manipulate.

Sample No. 79. Clearfield County, Greenwood Township: a flint clay owned by the Passmore Estate, Bells Landing, Pa. It was obtained from a natural outcrop of clay along the bank of Susquehanna River 1 mile below Bells Landing. The clay is hard and splintery; it is 6 feet thick, medium gray, unoxidized, has no surface stain, and is homogeneous. It is known as the "A" clay, Brookville horizon, but the Brookville coal is absent. The N. Y. C. R. R. runs through the property. Both fuel and labor supply are good. The plant was not operating in 1925. The sample shows a splintery fracture; is medium gray in color, very hard, and has poor plasticity.

The data obtained indicate that this is a high grade No. 1 fire clay.

Sample No. 80. Clearfield County, Greenwood Township: a flint clay owned by the Hoyt Estate, Bells Landing, Pa. It was obtained in the bed of Susquehanna River, 2 miles below Bells Landing. The clay is hard and splintery; it is 7 feet thick, dark gray, unoxidized, has a medium iron surface stain, and is a homogeneous mass. The bed is near the base of the Allegheny group at the Clarion or Brookville horizon, but the coal is absent. The N. Y. C. R. R. runs through the property; both fuel and labor supply are good. The clay is not developed. The sample is very hard, and has poor (sandy) plasticity.

The data obtained indicate that this is a high grade No. 1 fire clay.

Sample No. 81. Clearfield County, Greenwood Township: a shale owned by Robert L. Derrick, Clearfield, Pa. It was obtained ½ mile below Bells Landing along Susquehanna River in the Pennsylvania Coal & Clay Corp. mine No. 1. The shale is splintery; 9 feet thick, dark gray, unoxidized, has a slight carbon surface stain, and is a homogeneous mass. It underlies the Lower Kittanning or "B" coal. The N. Y. C. R. R. runs through the property; both fuel and labor supply are good. Coal is mined here but the shale is

not utilized. The sample is medium hard, has some carbon, and very good plasticity.

The data obtained indicate that this shale could probably be used for the production of face brick or tile. Its burning properties are satisfactory.

TESTS OF FIRE CLAYS AND OTHER CLAYS OF PENNSYLVANIA

(Walter Preische and David R. Mitchell, analysts)

Properties of Clays in Green State

No.	Water of plasticity Per cent of dry weight	Shrinkage water Per cent of dry weight	Pore water Per cent of dry weight	Time of slaking minutes	Drying shrinkage Per cent of dry volume
1	22.67	7.08	15.59	4	12.63
2	18.36	8.33	10.05	13	15.76
3	23.01	5.77	17.14	11	10.04
4	25.22	10.69	14.53	11	20.11
5	25.54	8.90	16.74	19	15.64
6	24.11	6.40	17.61	22	10.83
7	31.87	13.19	18.66	3¾	21.51
8	24.13	5.64	18.48	5½	9.96
9	21.13	7.07	14.06	6¾	13.05
10	21.48	5.50	15.99	3½	9.80
11	21.52	5.27	16.25	2¾	7.91
12	24.25	6.61	17.65	5	10.7
13	22.04	5.90	16.14	2	9.99
14	23.09	8.83	14.25	15¾	15.99
15	21.90	------	------	------	-2.76
16	24.13	9.16	14.97	9	17.16
17	21.37	8.60	12.77	3¾	16.14
18	24.84	8.20	16.63	5¼	14.63
19	26.06	9.47	16.59	5	16.50
20	21.64	11.33	10.31	4¾	20.92
21	24.10	8.38	15.62	2½	13.95
22	20.11	13.12	7.04	1½	2.23
23	20.77	5.45	15.33	5½	9.98
24	19.13	5.78	13.35	5½	10.97
25	20.06	9.11	10.95	5½	17.56
26	23.58	8.17	15.41	1¼	14.55
27	17.46	6.36	11.10	5	12.97
28	19.73	5.78	13.93	3	10.75
29	21.49	10.47	11.02	6½	19.59
30	18.92	5.93	12.99	6½	11.41
31	21.48	7.14	14.34	2½	12.26
32	21.42	7.77	13.65	6	14.83
33	20.33	6.26	14.07	26	11.70
34	25.10	10.86	14.24	6	20.18
35	23.33	6.83	16.50	3	12.26
36	23.10	7.18	15.92	6	12.92
37	24.80	8.10	16.70	4	14.17
38	24.85	10.05	14.80	5½	18.29
39	23.31	7.41	15.9	3	13.40
40	24.40	7.57	16.85	7	13.52
41	24.99	8.18	16.81	4½	14.72
42	21.61	5.80	15.82	4	9.85
43	22.56	6.88	16.67	11	11.36
44	21.03	4.10	16.93	3	6.90
45	22.72	5.47	17.25	2	9.33
46	23.28	9.16	14.34	13	16.70
47	23.57	7.66	15.91	3	13.34
48	24.34	6.91	17.43	9	12.17
49	22.20	6.15	16.05	3	10.67
50	27.36	9.98	17.37	7½	17.16
51	26.43	9.91	16.52	4½	17.98
52	23.96	6.90	17.06	2	12.04
53	17.01	2.08	14.93	3	4.00
54	24.99	8.53	16.52	8	15.13
55	21.43	4.93	16.50	3	8.93
56	23.06	8.44	14.62	2½	15.32
57	25.95	6.72	19.23	5	11.58

Properties of Clays in Green State—Continued

No.	Water of plasticity Per cent of dry weight	Shrinkage water Per cent of dry weight	Pore water Per cent of dry weight	Time of slaking minutes	Drying shrinkage Per cent of dry volume
58	24.66	7.11	17.55	5	12.66
59	28.06	4.65	23.95	22½	7.17
60	23.27	9.35	13.92	9½	17.60
61	19.13	5.94	13.18	4	11.65
62	23.80	5.58	18.22	5	9.62
63	23.11	3.68	17.43	2½	9.93
64	20.38	1.74	18.64	*	2.92
65	25.86	10.45	15.41	11½	18.38
66	26.88	7.28	19.60	10	12.43
67	27.98	10.29	17.69	4	17.70
68	23.06	5.71	17.35	11	10.20
69	25.85	5.90	19.95	6	9.61
70	22.78	6.54	16.24	10½	11.70
71	21.88	4.85	17.03	2½	7.72
72	22.56	5.25	17.31	5	9.35
73	24.66	7.67	16.99	9	13.57
74	25.30	7.86	17.44	4	13.35
75	29.94	8.92	21.02	6	14.17
76	22.58	7.32	15.26	13	13.57
77	20.85	5.50	15.35	6	10.63
78	23.94	8.72	15.12	4	16.38
79	24.50	7.37	17.13	3	12.30
80	24.14	6.48	17.62	1	10.85
81	21.49	4.90	16.59	7	8.69

*Does not slake

Fusion.

No.	Cone	Deg. C.	No.	Cone	Deg. C.	No.	Cone	Deg. C.	No.	Cone	Deg. C.
1.	31½	1695	21.	34	1740	41.	26	1600	61.	13	1390
2.	20	1530	22.	30	1670	42.	29	1650	62.	17	1470
3.	32	1705	23.	26½	1610	43.	26	1600	63.	32	1705
4.	20	1530	24.	18	1490	44.	26	1600	64.	32½	1712
5.	26½	1610	25.	26½	1610	45.	33½	1730	65.	16	1450
6.	26	1600	26.	30	1670	46.	26	1600	66.	13	1390
7.	28½	1642	27.	16	1450	47.	33	1720	67.	20	1530
8.	20	1530	28.	29	1650	48.	31	1685	68.	13	1390
9.	16	1450	29.	32	1705	49.	33	1720	69.	34	1740
10.	32	1705	30.	26	1600	50.	30	1670	70.	20	1530
11.	15½	1440	31.	29	1650	51.	29	1650	71.	29	1650
12.	26	1600	32.	26½	1610	52.	31½	1695	72.	20½	1565
13.	32	1705	33.	18	1490	53.	32½	1713	73.	27½	1628
14.	19	1510	34.	20½	1610	54.	29	1650	74.	20	1530
15.	34	1740	35.	30	1670	55.	30½	1678	75.	28	1635
16.	14	1410	36.	20	1530	56.	32	1705	76.	17	1470
17.	16	1450	37.	20	1530	57.	32	1705	77.	15	1430
18.	18	1490	38.	30	1670	58.	26½	1610	78.	15	1430
19.	17	1470	39.	26	1600	59.	16	1450	79.	35	1755
20.	20½	1565	40.	32	1705	60.	15	1430	80.	35	1755
									81.	18	1490

Burning Shrinkage

Figures represent volume shrinkage in per cent of dry volume.

Sample No.	Degrees Centigrade								
	1000	1050	1100	1150	1200	1250	1300	1350	1400
1	3.38	4.86	5.86	------	------	6.22	8.72	10.37	9.64
2	2.74	3.35	5.27	4.75	------	13.90	16.93	0.55	-0.82
3	4.92	5.18	6.32	6.06	15.82	16.15	17.10	17.80	23.74
4	10.6	18.0	16.6	20.2	20.8	21.5	19.4	10.3	2.5
5	----------	----------	8.16	7.02	30.2	30.1	30.30	26.70	8.79
6	0.0	2.50	3.56	3.63	------	17.85	25.22	10.33	10.05
7	0.60	5.04	5.98	4.16	------	20.48	25.60	------	13.77
8	7.54	10.17	9.55	11.64	29.20	------	30.10	24.84	9.66
9	0.84	1.71	2.84	3.15	12.32	11.73	22.09	-10.75	------
10	9.75	10.90	10.85	12.61	------	------	15.89	17.53	27.10
11	5.12	5.88	6.57	7.81	22.00	20.58	22.62	27.91	32.57
12	6.77	8.90	8.12	12.16	------	24.70	28.88	13.23	11.90
13	4.05	2.35	3.19	4.04	5.46	6.56	5.98	5.25	6.92
14	6.38	9.57	10.33	10.81	22.00	23.05	25.05	24.30	8.21
15	-1.87	-----	-.82	-1.34	0.00	0.00	.55	1.78	-25.60
16	7.04	13.48	14.91	17.71		19.36	-10.69	-28.85	------
17	6.02	10.33	10.62	11.77	16.92	20.38	13.86	-19.70	------
18	11.48	11.70	13.24	14.48	26.84	27.10	26.84	22.67	12.56
19	12.50	------	13.40	20.21	29.65	32.00	34.57	5.57	5.21
20	3.85	9.68	7.92	10.34	------	22.22	22.86	11.68	2.75
21	13.58	13.32	14.80	14.36	20.60	20.78	20.00	19.75	17.00
22	10.41	13.08	11.82	15.32	14.82	15.15	15.32	14.21	14.25
23	3.59	6.16	6.46	8.43	------	17.62	18.13	11.02	9.47
24	4.54	8.07	7.21	10.40	20.62	21.16	21.38	1.10	.83
25	1.76	------	2.31	3.54	17.87	17.95	20.78	19.37	9.74
26	3.07	4.18	6.31	7.93	8.18	8.15	11.08	7.27	6.00
27	.87	1.74	2.87	6.95	------	11.54	12.50	6.58	-7.45
28	2.17	3.86	5.39	8.47	8.52	9.86	6.06	6.96	10.23
29	6.11	11.47	8.40	13.00	------	19.78	21.82	15.00	14.45
30	4.49	5.42	5.18	6.73	------	14.36	18.28	8.17	4.22
31	8.28	10.60	11.32	------	14.09	15.00	13.40	14.86	13.55
32	3.29	------	8.09	9.63	13.02	13.72	14.70	9.74	4.13
33	.56	6.09	6.42	8.76	------	15.00	19.75	21.10	11.50
34	9.38	15.78	16.04	17.27	------	22.16	21.90	14.93	------
35	6.58	8.88	8.98	9.71	8.22	9.76	------	11.51	9.74
36	-.57	11.30	12.71	14.81	------	21.63	24.70	15.98	7.08
37	7.87	7.83	8.91	11.45	------	24.06	25.08	24.30	10.95
38	4.54	8.16	8.13	12.91	19.64	19.86	20.00	19.43	19.43
39	5.26	9.52	9.92	11.12	14.88	20.42	21.13	10.52	8.26
40	3.13	------	9.88	12.98	------	19.82	22.25	20.34	19.00
41	3.53	8.60	7.07	9.85	------	19.75	23.00	18.90	12.05
42	9.75	9.44	9.94	9.98	12.74	12.48	11.07	12.85	10.63
43	4.82	------	4.72	8.88	------	18.80	19.67	15.00	9.15
44	.76	1.03	3.84	7.48	------	14.28	18.35	9.30	8.44
45	13.62	14.33	15.55	15.85	------	17.82	19.65	21.00	19.77
46	0.00	3.79	2.33	8.42	------	20.22	25.50	25.00	9.34
47	12.50	14.14	13.88	18.48	------	19.40	17.23	23.40	22.24
48	2.30	10.43	10.48	14.80	------	21.34	22.60	27.83	31.80
49	13.73	15.32	14.08	14.51	------	19.18	21.47	22.67	26.00
50	8.03	11.97	13.63	18.15	------	25.65	29.60	28.82	32.75
51	-7.55	13.34	12.53	16.76	------	21.47	20.97	24.90	19.45
52	10.79	13.22	14.76	14.93	------	19.77	19.54	21.43	25.35
53	.77	1.83	0.00	-2.00	1.28	-2.53	0.00	6.55	8.42
54	7.07	10.42	10.92	13.98	------	24.90	24.85	26.20	16.60
55	12.33	14.17	14.45	21.68	21.86	23.05	22.74	22.10	21.44
56	8.41	13.31	13.62	17.41	19.75	21.13	21.60	20.66	24.25
57	7.27	13.90	12.05	14.96	------	25.60	24.50	27.48	23.70
58	6.13	------	13.25	19.18	------	24.90	27.30	28.00	22.05
59	7.24	10.41	10.08	14.22	------	30.70	34.00	30.80	19.83
60	11.81	15.72	17.23	22.86	------	10.35	-19.45	-63.40	------
61	1.71	3.64	7.58	7.89	------	11.82	17.36	------	------
62	-2.80	3.40	6.65	8.04	------	17.45	22.15	6.94	
63	8.84	15.82	13.29	15.57	------	17.45	19.76	24.28	26.90
64	0.00	5.76	------	6.06	------	11.12	11.95	12.55	15.77
65	.29	3.89	5.06	6.52	------	9.70	16.43	11.70	
66	11.14	15.88	20.40	32.69	------		-21.88		
67	11.40	------	17.77	19.70	------	28.13	28.54	18.60	16.15

Burning Shrinkage—Continued

Sample No.	Degrees Centigrade								
	1000	1050	1100	1150	1200	1250	1300	1350	1400
68	1.39	------	10.55	19.91	------	26.38	20.24	6.16	
69	13.30	15.30	------	15.20	20.70	20.18	20.73	19.26	22.05
70	2.84	------	9.80	12.28	------	17.36	22.66	20.40	6.90
71	2.25	------	2.77	4.52	------	5.52	5.95	9.47	8.60
72	6.48	6.67	11.36	15.07	------	19.76	24.10	19.90	10.47
73	12.96	14.76	16.90	17.30	------	25.07	26.57	20.40	18.70
74	3.13	10.35	12.03	14.67	------	23.78	24.50	9.30	10.25
75	0.00	0.00	1.96	5.43	9.58	9.77	11.22	12.42	5.56
76	6.53	------	14.87	16.75	------	22.25	22.10	10.93	.87
77	13.48	18.02	20.18	21.75	24.36	28.10	20.20	13.60	
78	------	------	20.50	30.01	- ----	22.38	5.64	-.59	
79	------	16.35	16.75	17.18	------	------	22.04	22.26	22.90
80	13.48	16.84	16.27	------	21.30		22.62	21.84	24.90
81	5.96	------	6.01	7.61	17.03	17.60	20.87	20.90	21.90

Porosity

Figures represent per cent porosity in terms of burned volume.

Sample No.	Degrees Centigrade								
	1000	1050	1100	1150	1200	1250	1300	1350	1400
1	34.02	33.9	35.1	32.4	------	30.8	32.8	31.9	31.9
2	31.1	28.9	30.8	30.4	------	16.0	10.0	10.2	5.9
3	35.7	35.1	35.9	35.4	28.9	29.5	28.3	24.8	20.3
4	19.6	10.32	15.95	12.95	5.32	3.89	1.98	5.03	9.36
5	------	32.3	29.9	25.1	7.52	8.7	1.7	0.0	10.0
6	39.7	36.4	------	36.7	------	21.2	11.7	14.8	6.5
7	40.9	39.6	42.7	38.7	------	20.7	15.1	------	10.9
8	27.7	24.9	25.3	26.4	2.9	------	0.0	0.0	3.1
9	31.5	32.1	34.2	33.0	------	20.9	15.7	19.7	------
10	34.5	34.4	34.2	35.1	31.3	29.8	28.6	25.2	15.7
11	47.7	47.0	48.3	47.6	------	39.0	33.8	27.6	6.0
12	37.3	33.9	36.1	35.4	------	19.4	------	14.3	12.9
13	36.2	37.1	36.8	36.9	36.3	34.2	36.5	35.6	34.6
14	31.3	26.6	29.8	26.6	------	12.6	10.0	3.8	9.9
15	45.9	46.3	40.1	47.4	47.6	47.1	43.7	47.1	32.2
16	19.6	14.2	------	15.8	------	3.3	17.5	0.48	------
17	28.9	24.2	26.7	24.2	10.7	11.7	10.5	20.9	------
18	25.5	21.0	28.2	25.0	6.6	8.3	6.8	3.0	7.2
19	25.3	------	27.5	24.1	0.8	0.0	0.0	10.8	28.8
20	31.6	27.1	31.0	31.4	------	12.0	5.1	3.1	10.9
21	34.7	35.3	38.1	35.5	33.2	34.2	33.3	32.7	35.3
22	37.6	39.3	38.9	30.7	36.9	35.6	35.5	35.9	37.6
23	33.4	28.4	31.9	29.6	------	20.3	16.3	11.8	6.5
24	28.9	27.7	30.1	30.0	------	12.4	4.9	8.7	6.3
25	28.5	27.6	31.5	29.0	------	13.9	8.5	4.5	6.0
26	35.0	35.3	37.5	37.6	35.6	33.1	34.1	32.8	30.5
27	28.4	25.6	28.6	27.8	------	17.0	12.2	8.2	13.6
28	32.7	33.1	33.2	35.4	32.3	30.4	31.0	29.8	27.6
29	30.2	24.7	27.1	25.7	------	14.1	9.2	6.8	6.0
30	24.6	23.5	25.7	24.2	------	15.2	12.7	10.9	3.3
31	34.5	34.9	35.5	34.9	33.6	32.7	32.7	32.3	34.7
32	28.9	26.9	29.4	27.5	------	20.7	19.2	14.3	8.6
33	33.5	30.6	31.8	31.7	------	19.9	11.4	7.2	6.7
34	24.1	19.7	22.8	20.9	------	13.3	9.9	4.9	------
35	36.5	37.1	38.5	38.5	35.9	35.0	------	35.6	30.8
36	25.5	26.8	30.8	28.3	------	12.4	8.5	7.9	2.1
37	32.6	------	32.9	30.1	------	13.1	9.5	4.1	8.7
38	30.8	------	31.4	30.4	------	18.3	19.2	7.9	3.7
39	32.9	29.0	31.2	29.5	------	19.7	14.9	14.9	10.5
40	30.6	------	30.5	28.7	------	15.5	12.4	9.1	5.4
41	28.1	28.1	30.7	27.9	------	13.7	8.1	8.5	10.4
42	38.2	39.1	38.9	37.9	37.5	35.5	36.6	37.4	37.5
43	36.9	35.0	37.5	37.1	20.9	21.6	15.0	16.7	3.3

Porosity—Continued

Sample No.	Degrees Centigrade								
	1000	1050	1100	1150	1200	1250	1300	1350	1400
44	37.7	35.7	38.8	38.5	------	26.3	21.5	19.9	13.4
45	34.9	33.7	36.4	34.9	33.2	30.6	31.6	30.4	27.9
46	31.5	28.9	31.1	30.9	------	10.1	3.8	0.0	2.3
47	35.1	32.9	34.9	34.7	------	27.6	27.4	27.4	23.9
48	33.5	30.8	33.5	31.4	------	19.8	15.4	13.2	8.6
49	34.7	33.3	35.7	33.7	31.3	30.1	30.1	28.6	27.3
50	31.9	------	31.7	29.4	------	17.6	15.7	9.8	1.3
51	24.9	23.5	26.8	25.8	------	15.2	12.1	9.6	2.7
52	33.8	31.8	35.2	34.3	------	29.2	29.2	28.0	24.3
53	46.9	47.2	48.5	48.2	46.7	42.9	46.7	42.9	43.5
54	25.2	21.5	27.1	24.7	------	13.6	8.9	5.3	4.7
55	32.2	30.7	32.9	32.7	28.1	25.3	25.3	22.8	21.2
56	31.3	28.2	31.2	31.2	26.5	25.0	23.8	22.0	24.8
57	25.3	31.4	34.3	33.5	------	23.7	21.7	19.0	12.5
58	29.9	------	28.0	25.3	------	8.0	7.9	4.9	3.4
59	41.5	37.9	41.2	37.9	------	12.3	6.9	1.1	7.6
60	15.9	------	15.2	9.7	------	7.2	18.3	27.6	------
61	34.1	33.8	31.5	32.1	------	25.3	0.0	------	------
62	32.3	32.6	35.1	34.9	------	19.0	13.2	7.8	------
63	34.6	31.1	34.2	31.8	------	22.5	27.1	22.1	18.1
64	44.1	46.6	45.4	46.1	45.4	43.6	44.4	44.0	43.5
65	33.0	31.0	33.5	30.4	------	23.1	21.4	4.8	------
66	26.1	15.4	22.6	20.6	18.5	------	28.5	------	------
67	32.0	------	29.9	25.9	------	9.5	9.8	10.0	7.0
68	31.7	------	30.1	28.9	------	5.4	5.7	7.5	------
69	38.7	37.9	------	38.7	36.4	35.0	35.1	34.6	34.4
70	31.1	------	30.9	29.5	------	16.8	12.2	5.4	4.3
71	44.3	------	44.5	44.4	------	41.0	41.6	41.8	37.9
72	33.0	29.6	33.5	32.5	------	21.3	17.3	10.5	8.0
73	28.1	------	27.9	24.7	------	13.1	11.2	9.8	4.3
74	35.1	------	34.7	32.1	------	17.0	10.1	14.6	8.7
75	35.6	34.7	36.1	35.9	30.3	31.2	28.8	26.5	27.5
76	24.9	------	20.3	17.0	------	4.8	9.1	10.3	10.5
77	29.9	21.4	29.7	22.8	7.7	3.5	13.2	15.4	------
78	------	------	15.5	10.8	------	1.8	7.0	10.5	------
79	39.4	37.0	38.1	37.4	------	------	33.8	32.2	34.6
80	35.2	33.5	36.7	33.5	33.3	------	31.4	30.9	28.0
81	35.8	------	34.5	32.5	18.2	18.8	11.8	11.7	2.1

Apparent Specific Gravity

Sample No.	Degrees Centigrade								
	1000	1050	1100	1150	1200	1250	1300	1350	1400
1	2.56	2.60	2.64	2.70	------	2.48	2.64	2.53	2.58
2	2.63	2.56	2.65	2.65	------	2.43	2.36	1.97	1.84
3	2.63	2.61	2.64	2.63	2.66	2.70	2.69	2.59	2.64
4	2.46	2.39	2.51	2.52	2.35	2.33	2.22	2.07	1.99
5	------	2.76	2.55	2.37	2.37	2.37	2.38	2.12	2.05
6	2.65	2.58	2.63	2.63	------	2.48	2.43	2.10	1.89
7	2.61	2.66	2.77	2.67	------	2.42	2.45	------	1.98
8	2.51	2.45	2.79	2.52	2.45	------	2.36	2.20	1.88
9	2.58	2.62	2.75	2.70	2.38	2.49	2.47	1.96	------
10	2.66	2.69	2.68	2.75	2.98	2.78	2.62	2.55	2.55
11	2.72	2.71	2.75	2.78	2.66	2.69	2.63	2.56	2.11
12	2.64	2.56	2.63	2.71	------	2.54	2.39	2.06	2.01
13	2.60	2.59	2.59	2.62	2.63	2.56	2.66	2.59	2.36
14	2.65	2.55	2.57	2.69	2.36	2.51	2.51	2.24	2.05
15	3.15	3.05	3.26	3.26	3.31	3.28	3.11	3.33	2.98
16	2.35	2.35	2.60	2.52	------	2.24	1.92	1.59	------
17	2.56	2.51	2.61	2.55	2.26	2.40	2.21	1.80	------
18	2.51	2.34	2.60	2.58	2.41	2.48	2.43	2.23	2.03
19	2.48	------	2.57	2.66	2.31	2.38	2.48	2.07	1.71
20	2.56	2.51	2.59	2.68	------	2.42	2.27	1.84	1.90
21	2.56	2.56	2.66	2.59	2.70	2.71	2.69	2.67	2.67

Apparent Specific Gravity—Continued

Sample No.	Degrees Centigrade								
	1000	1050	1100	1150	1200	1250	1300	1350	1400
22	2.60	2.75	2.69	2.46	2.70	2.60	2.67	2.64	2.60
23	2.67	2.59	2.68	2.65	------	2.60	2.51	2.18	1.97
24	2.58	2.63	2.68	2.80	2.47	2.52	2.35	1.94	1.85
25	2.56	2.64	2.61	2.61	2.49	2.54	2.48	2.33	2.11
26	2.56	2.55	2.69	2.74	2.71	2.60	2.66	2.59	2.46
27	2.67	2.59	2.71	2.81	------	2.56	2.45	2.20	2.12
28	2.57	2.62	2.63	2.85	2.71	2.59	2.59	2.57	2.71
29	2.52	2.58	2.68	2.66	------	2.49	2.43	2.18	2.14
30	2.54	2.53	2.66	2.60	------	2.52	2.57	2.25	1.97
31	2.66	2.63	2.54	2.59	2.68	2.62	2.62	2.65	2.71
32	2.58	2.57	2.67	2.69	2.52	2.58	2.56	2.29	2.01
33	2.68	2.72	2.67	2.74	------	2.56	2.48	2.42	2.12
34	2.48	2.50	2.62	2.59	------	2.52	2.43	2.11	------
35	2.71	2.78	2.82	2.88	2.69	2.69	------	2.80	2.64
36	2.27	2.59	2.71	2.76	------	2.47	2.42	2.18	1.86
37	2.66	2.53	2.66	2.67	------	2.47	2.51	2.29	1.88
38	2.52	2.61	2.64	2.73	2.40	2.53	2.56	2.24	2.11
39	2.66	2.61	2.68	2.66	2.23	2.61	2.46	2.19	2.02
40	2.51	------	2.65	2.69	------	2.46	2.45	2.31	2.20
41	2.44	2.57	2.62	2.61	------	2.43	2.40	2.47	2.16
42	2.69	2.71	2.71	2.68	2.74	2.62	2.65	2.70	2.66
43	2.62	2.59	2.63	2.73	2.53	2.47	2.31	2.22	1.79
44	2.51	2.48	2.68	2.78	------	2.51	2.47	2.18	2.00
45	2.61	2.59	2.73	2.66	2.79	2.62	2.67	2.67	2.55
46	2.52	2.52	2.55	2.71	------	2.39	2.40	2.30	1.93
47	2.65	2.61	2.67	2.78	------	2.63	2.50	2.71	2.53
48	2.43	2.54	2.63	2.81	------	2.52	2.40	2.51	2.49
49	2.65	2.68	2.69	2.63	2.74	2.69	2.72	2.71	2.76
50	2.48	2.39	2.63	2.67	------	2.52	2.61	2.42	2.24
51	2.06	2.48	2.58	2.67	------	2.48	2.37	2.44	2.14
52	2.59	2.57	2.74	2.67	------	2.65	2.66	2.69	2.70
53	3.16	3.18	3.20	3.12	3.20	2.75	3.11	3.18	3.17
54	2.39	2.36	2.56	2.52	------	2.51	2.42	2.37	2.08
55	2.65	2.64	2.72	3.03	2.78	2.78	2.73	2.61	2.55
56	2.57	2.59	2.71	2.84	2.74	2.67	2.71	2.61	2.78
57	2.55	2.59	2.65	2.69	------	2.73	2.79	2.61	2.31
58	2.53	------	2.65	2.72	------	2.39	2.47	2.42	2.18
59	2.68	2.59	2.73	2.73	------	2.37	2.37	2.12	1.95
60	2.39	2.40	2.56	2.55	------	2.12	1.82	1.50	------
61	2.64	2.67	2.73	2.75	------	2.55	2.07	------	------
62	2.41	2.56	2.68	2.79	------	2.49	2.49	1.96	------
63	2.63	2.69	2.73	2.71	------	2.44	2.67	2.65	2.56
64	2.67	2.94	3.02	1.94	2.00	2.96	3.04	3.03	3.15
65	2.57	2.68	2.69	2.68	------	2.47	2.60	2.03	------
66	2.49	2.29	2.65	3.05	1.40	------	1.88	------	------
67	2.65	------	2.75	2.68	------	2.45	2.48	2.17	2.06
68	2.56	------	2.76	3.04	------	2.46	2.30	1.95	------
69	2.65	2.67	------	2.70	2.78	2.68	2.74	2.67	2.75
70	2.55	------	2.73	2.75	------	2.48	2.51	2.26	1.91
71	2.68	------	2.70	2.72	------	2.62	2.66	2.74	2.55
72	2.59	2.47	2.76	2.83	------	2.58	2.59	2.27	1.98
73	2.59	2.47	2.71	2.59	------	2.48	2.46	2.25	2.08
74	2.53	2.57	2.75	2.74	------	2.00	2.54	2.04	1.96
75	2.44	2.48	2.49	2.70	2.49	2.45	2.48	2.44	2.28
76	2.48	------	2.56	2.52	------	2.35	2.24	2.18	1.96
77	2.83	2.65	3.04	2.82	2.43	2.46	2.46	2.33	------
78	------	------	2.63	2.82	------	2.32	2.06	1.96	------
79	2.85	2.73	2.78	2.77	------	------	2.79	2.73	2.83
80	2.61	2.59	2.76	2.51	2.77	------	2.75	2.71	2.70
81	2.80	------	2.74	2.71	2.49	2.52	2.43	2.43	2.18

Average and Range of Per cent of Green and Fired Properties

		19 Flint Clays		32 Plastic Clays		10 Shales		15 Semi-Flint Clays	
Green Properties		Aver-age	Range	Aver-age	Range	Aver-age	Range	Aver-age	Range
Shrinkage water		6.6	1.3— 8.4	7.8	4.1—11.3	7.5	5.6— 9.4	7.6	4.7—13.1
Pore water		15.3	13.9—20.0	15.8	10.3—21.0	15.5	12.8—18.2	16.1	10.1—24.0
Water of plasticity		22.2	17.0—24.5	23.6	18.0—29.9	23.0	20.9—24.8	23.7	17.5—31.9
Volume shrinkage		9.8	2.2—14.0	14.0	6.9—20.9	13.7	8.7—17.6	13.6	7.2—21.5
Linear shrinkage		3.2	1.3— 5.3	4.2	3.0— 6.0	4.5	2.8— 5.5	4.7	3.0— 7.0
Slaking time (minutes)		3.4	1.0—11.0	7.4	2.5—26.0	7.6	4.0—15.8	7.7	2.0—22.5
Fired Properties									
Volume Shrinkage	°C								
	1000	8.4	0.0—13.7	4.7	−7.6—13.0	6.8	−2.8—13.5	6.0	0.4—11.0
	1100	10.4	0.0—18.1	9.5	2.0—17.8	13.0	6.0—20.5	9.6	2.9—16.6
	1200	13.1	1.3—21.3	17.9	9.6—29.7	21.2	15.9—26.8	22.6	11.5—30.7
	1300	15.2	6.0—22.6	22.7	14.7—34.6	15.5	5.6—26.8	21.7	8.7—34.0
	1400	16.3	6.0—27.1	12.7	.8—32.8	8.5	8.2—28.9	11.5	7.5—24.3
Apparent Porosity	°C								
	1000	37.3	32.7—46.9	29.8	24.9—37.7	27.9	15.9—35.8	32.4	19.6—41.5
	1100	37.8	33.2—48.5	30.8	20.3—38.8	27.2	15.2—34.5	31.8	16.0—42.7
	1200	34.8	28.9—46.7	17.2	0.8—20.9	10.8	6.6—18.2	16.2	5.2—30.9
	1300	34.3	27.4—46.7	12.2	0.0—28.8	9.9	3.3—18.3	13.2	0.0—32.8
	1400	31.8	15.7—43.5	8.3	2.1—28.8	8.5	2.1—14.8	14.5	3.1—31.9
Apparent Specific Gravity	°C								
	1000	2.67	2.56—3.16	2.52	2.06—2.68	2.52	2.14—2.83	2.07	2.46—2.86
	1100	2.72	2.54—3.20	2.65	2.49—2.75	2.58	2.56—3.04	2.12	2.51—2.79
	1200	2.76	2.63—3.20	2.53	2.30—2.81	2.27	1.86—2.49	2.58	2.35—2.86
	1300	2.70	2.50—3.11	2.46	2.24—2.67	2.25	1.82—2.51	2.52	2.07—2.73
	1400	2.68	2.53—3.17	2.07	1.71—2.56	1.96	1.59—2.18	2.17	1.85—2.78
Fusion Cone		31–32+	29—35	25—26	17—32	16	13—19	23—24	13—31½

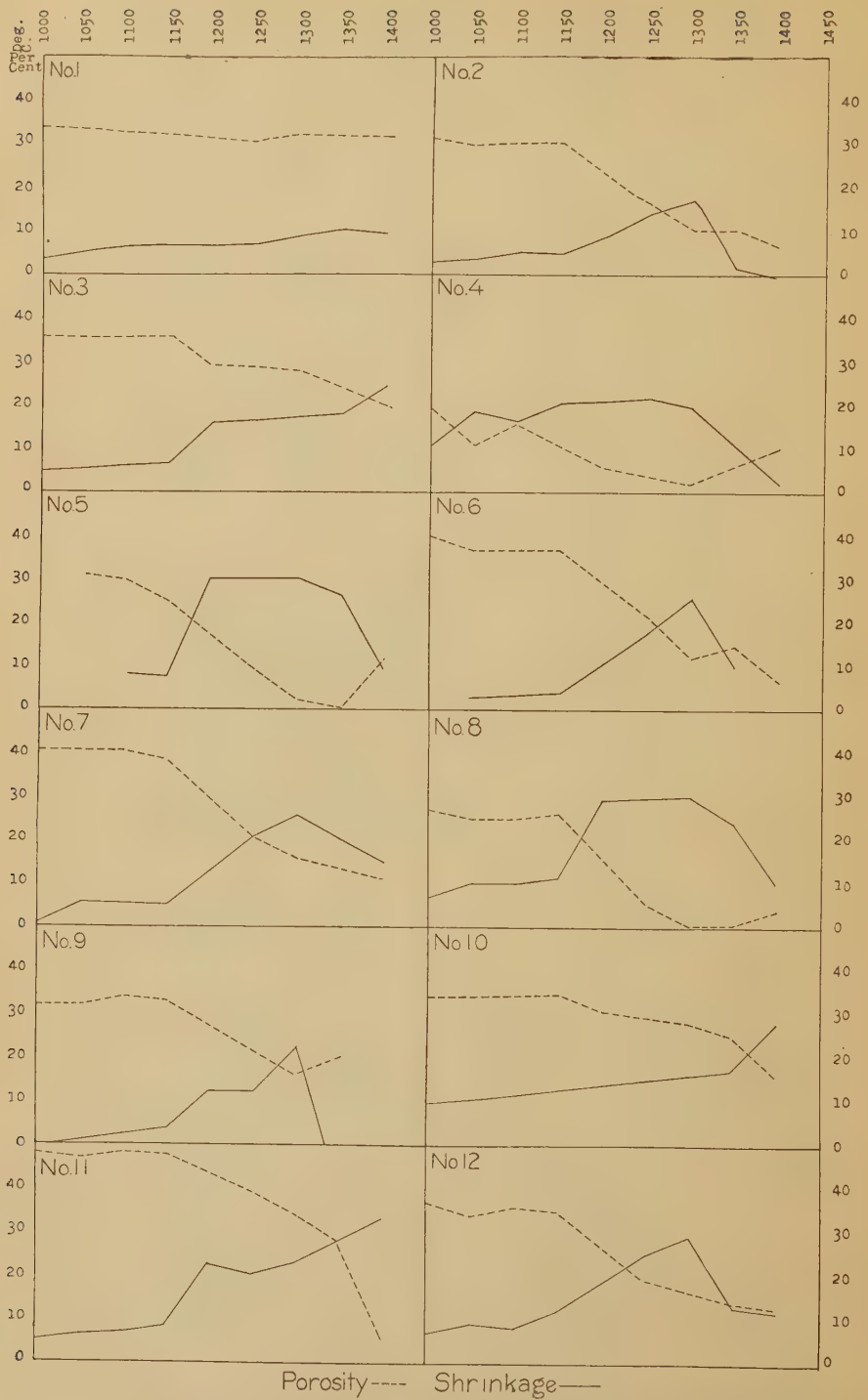


Figure 3. Graphs showing shrinkage and porosity of samples 1-12.

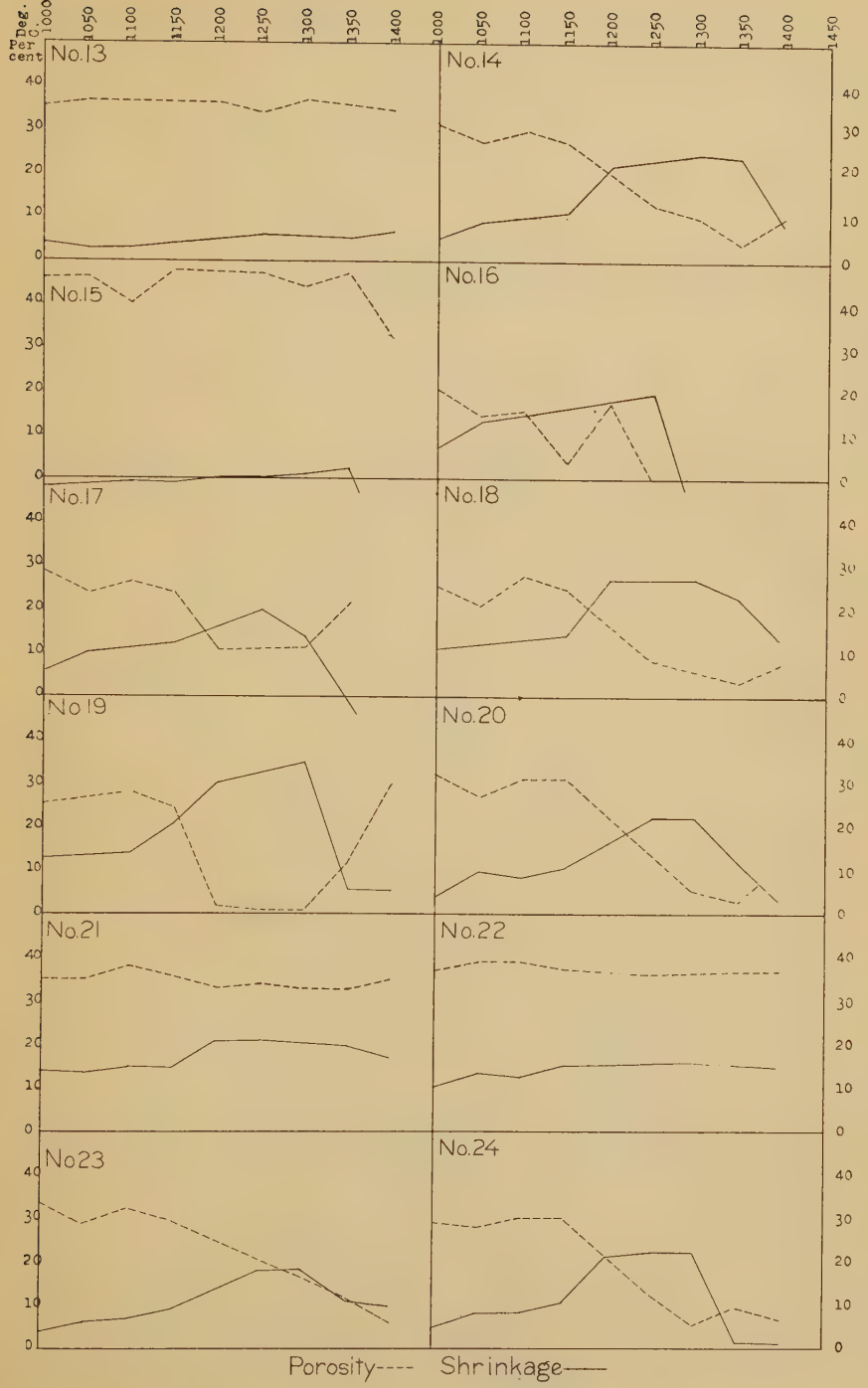


Figure 4. Graphs showing shrinkage and porosity of samples 13-24.

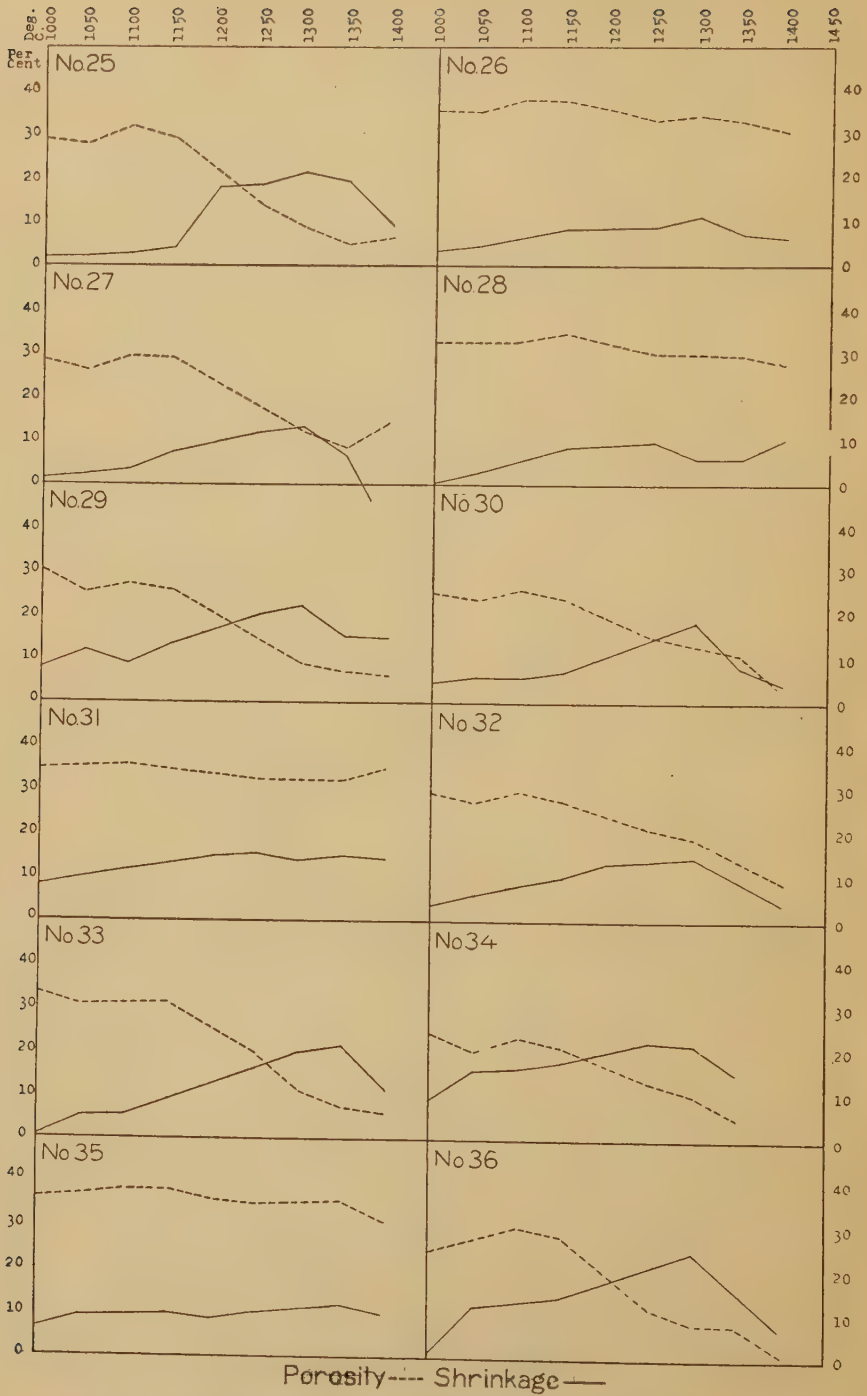


Figure 5. Graphs showing shrinkage and porosity of samples 25-36.

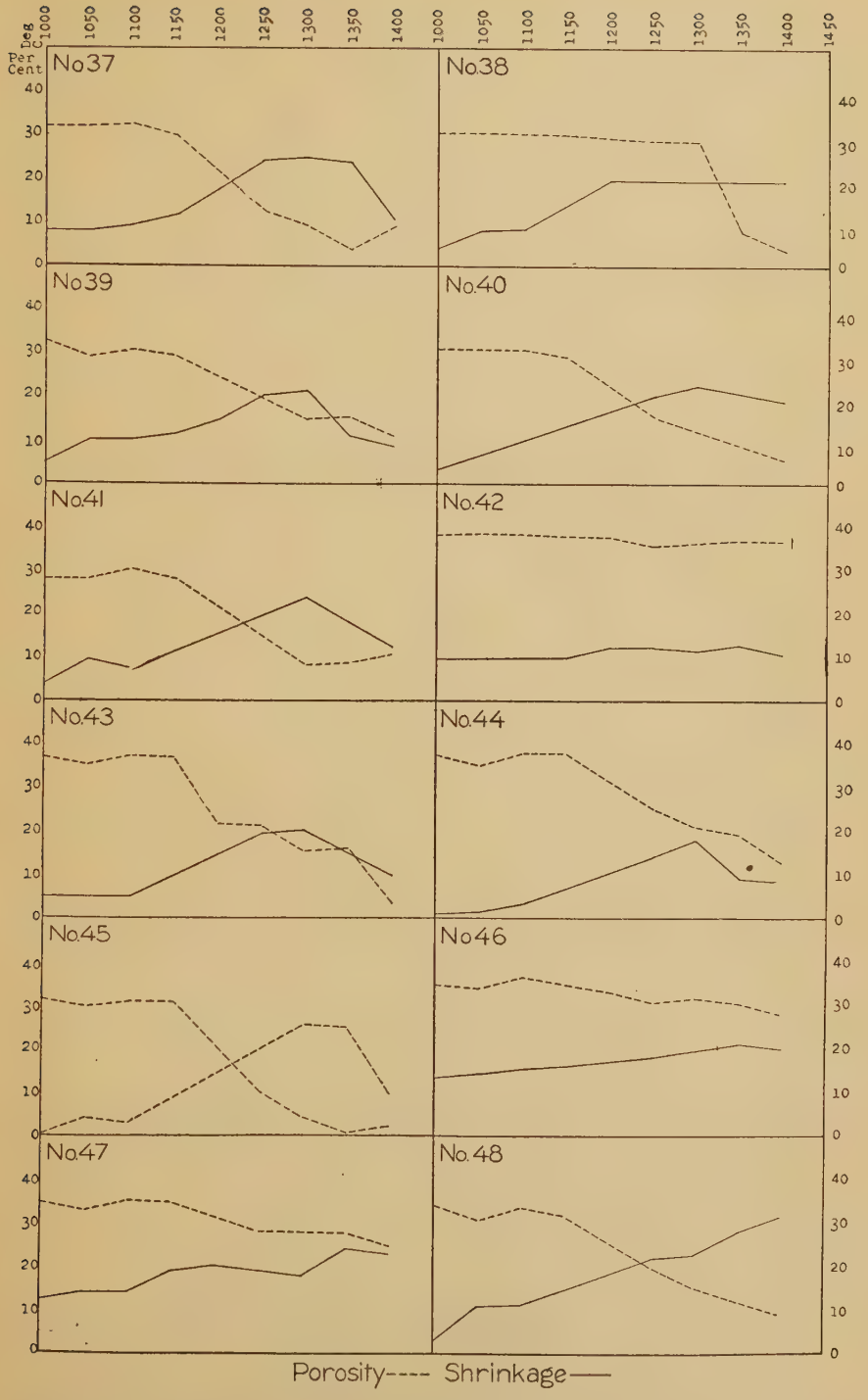


Figure 6. Graphs showing shrinkage and porosity of samples 37-48.

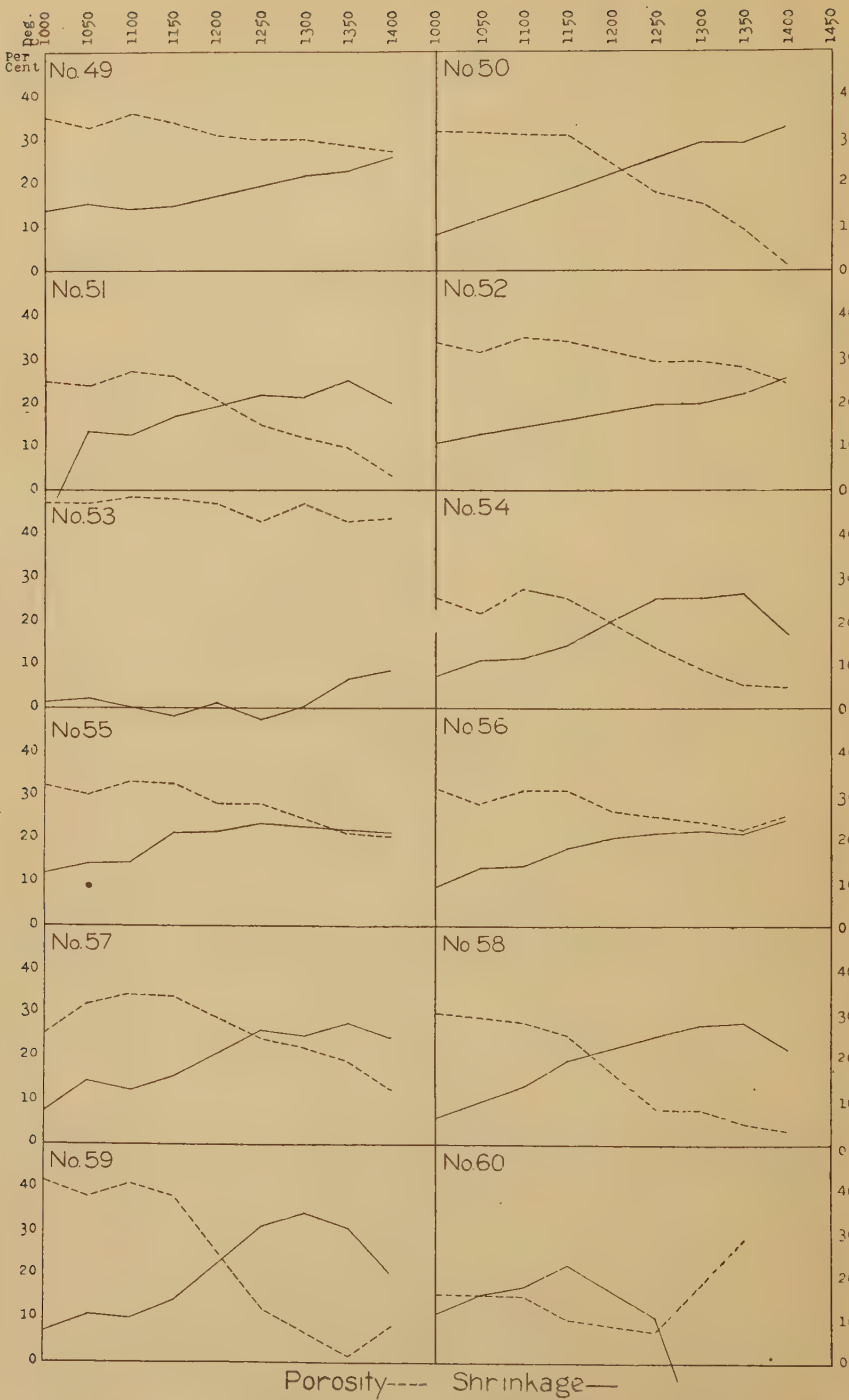


Figure 7. Graphs showing shrinkage and porosity of samples 49-60.

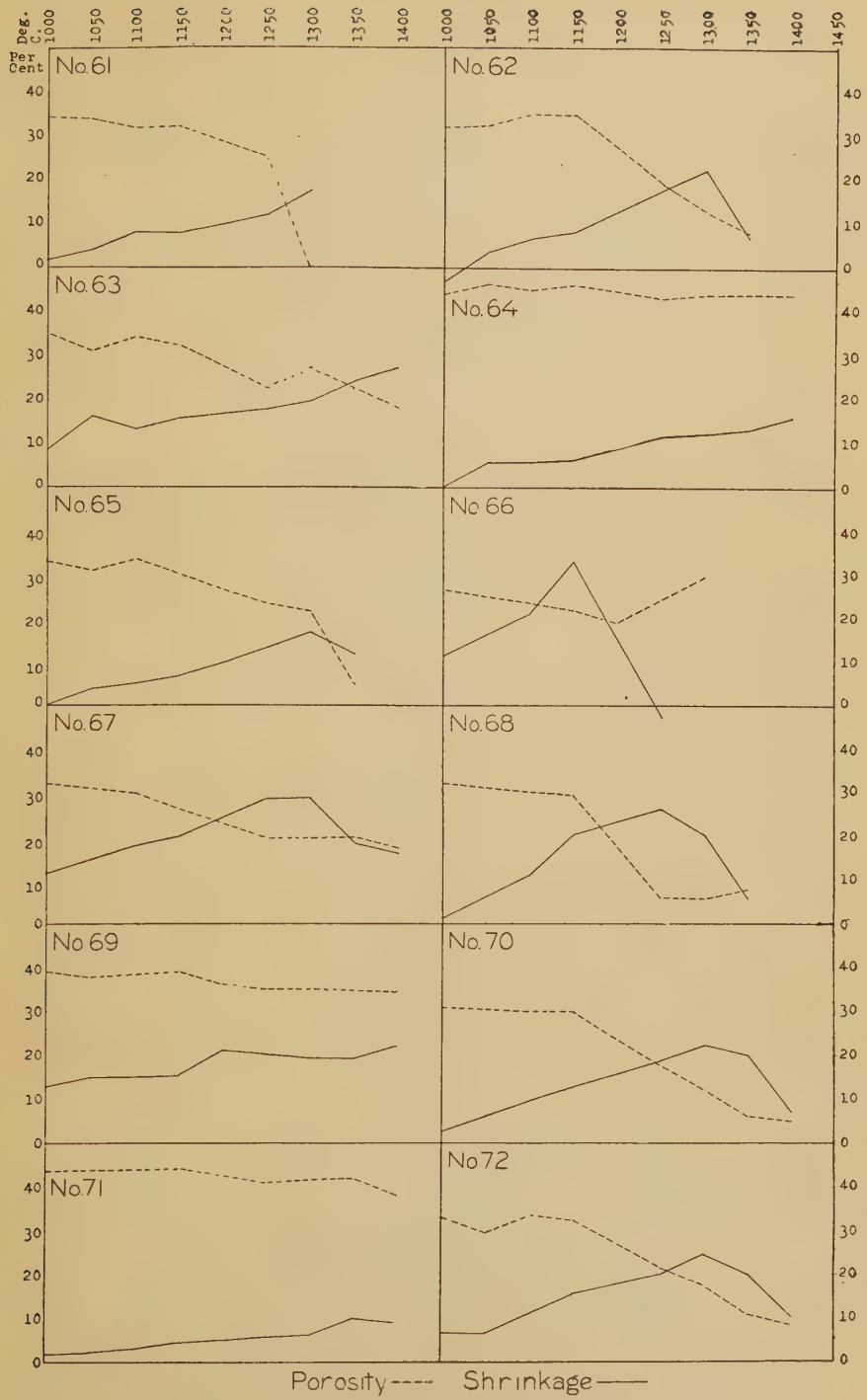


Figure 8. Graphs showing shrinkage and porosity of samples 61-72.

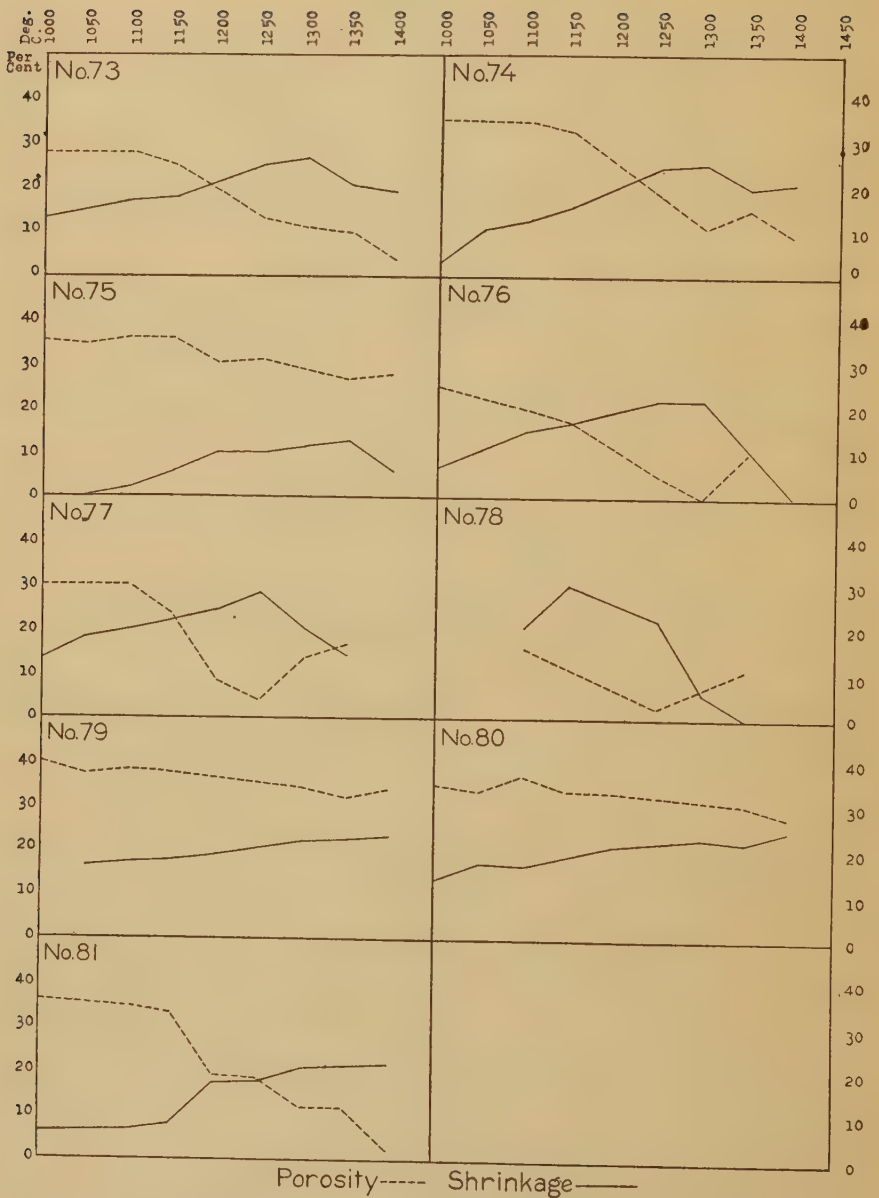


Figure 9. Graphs showing shrinkage and porosity of samples 73-81.

CHEMICAL ANALYSES

The chemical analyses, only 48 of which have been completed, were made by students in chemistry and ceramics at Pennsylvania State College under the supervision of Prof. T. W. Mason. While these chemical analyses are the work of students, it is believed they are sufficiently accurate to justify their publication. A check analysis was made by the students in every case, and analyses of some of the same clays made by commercial laboratories agree very closely with the results obtained by the students.

Chemical Analyses of Fire Clays and Other Clays.

[Made under supervision of Prof. T. W. Mason, State College.]

No.	Loss on Ignition	SiO_2	Fe_2O_3	TiO_2	Al_2O_3	CaO	MgO	Na_2O	K_2O	MnO	SO_3	P_2O_5
1	10.10	55.58	3.97	.015	28.62	.81	.63	.08	.21	.02	.04	.00
2	7.33	61.92	3.51	.28	23.56	.50	.89	.87	1.11	.07	.08	.008
3	12.43	46.25	3.38	.26	37.50	.16	.27	.54	.28	----	----	----
4	7.65	48.28	2.96	.61	29.91	2.56	1.01	3.72	3.09	----	----	----
5	5.10	62.80	2.23	.47	26.31	.97	.04	2.81	.34	----	----	----
6	5.65	65.69	3.91	.37	18.65	1.27	1.35	.59	2.08	.006	----	.03
7	6.48	60.65	4.60	.18	23.80	.30	.90	.56	1.12	.00	1.64	.03
8	5.42	59.23	3.52	.87	26.46	1.32	1.23	.46	.86	.03	.18	.02
9	4.91	70.68	6.97	.62	13.18	1.17	.98	.78	.42	.06	.22	.18
10	12.58	47.66	4.12	.19	32.90	.64	.95	.95	.50	----	----	----
11	9.50	58.33	7.52	1.28	17.44	2.07	1.70	.24	.36	.05	1.61	.02
12	7.63	61.99	4.24	.79	23.08	.66	.15	.47	.56	.16	.24	.08
13	8.58	62.75	1.85	.86	23.02	1.50	.74	.21	.33	.02	.63	.06
14	------	58.26	3.71	1.50	28.81	.47	.38	----	----	----	----	----
16	8.43	55.51	6.11	.64	21.14	3.19	1.10	.54	1.06	.09	2.39	.04
17	12.32	51.53	3.67	.17	28.22	.92	.81	1.08	.85	.17	.06	.15
18	8.20	55.67	3.00	.79	25.70	1.01	1.06	.58	1.07	.00	.78	.04
20	10.83	58.83	3.27	.22	22.78	.66	.68	1.49	1.09	.04	.10	.012
21	3.81	46.57	3.78	.17	36.52	1.27	1.41	2.01	4.40	.05	.08	.03
22	12.40	51.74	3.47	.17	28.33	.91	.86	1.02	.85	.00	.045	.13
23	6.87	59.54	2.62	.76	27.52	.70	1.17	1.04	.62	----	----	----
24	7.79	57.95	4.02	.33	25.68	1.21	1.39	.96	.78	----	----	----
25	6.93	58.53	3.68	1.47	28.73	.44	.36	----	----	----	----	.08
26	3.91	62.98	7.10	1.09	17.21	1.98	1.49	.83	2.05	.15	.40	.21
27	6.81	58.33	5.74	.72	24.14	2.02	1.09	.59	.92	.03	.18	.04
29	9.92	53.50	1.19	.07	29.45	1.42	.25	1.84	1.52	.27	.50	.006
31	12.50	52.80	.50	----	32.70	.18	.22	----	----	----	----	----
33	5.95	64.18	4.43	1.09	19.72	.89	----	----	----	----	----	----
37	5.94	60.07	9.84	1.32	14.64	.78	.45	----	----	----	----	----
38	10.22	53.62	.52	----	32.71	.21	.29	----	----	.24	----	----
39	8.55	54.99	1.92	1.64	28.45	.50	----	----	----	----	----	----
40	7.90	58.38	2.88	1.19	27.65	.41	1.08	.20	.31	----	.15	.085
41	9.37	63.56	4.71	1.05	19.96	.87	.46	----	----	.02	.17	.03
42	8.34	53.24	2.61	.86	32.85	.63	.82	.23	.32	.15	2.86	.18
43	4.83	69.92	4.63	.89	16.83	.59	.42	.45	.93	.04	.32	.15
44	6.15	62.75	2.72	2.43	21.55	----	.66	----	----	----	----	----
50	4.57	44.88	5.12	.056	37.70	1.13	1.11	----	----	----	----	.61
51	-------	45.65	9.01	.073	--------	2.04	1.74	-------	-------	4.73	-------	------
53	13.22	70.14	8.41	----	----	----	----	----	----	----	----	----
54	8.70	51.49	8.12	.83	13.25	----	----	----	----	----	----	----
65	5.13	73.56	13.98	.93	11.63	.73	----	----	----	----	----	----
67	8.00	53.80	2.27	.60	30.49	1.96	1.09	.60	1.03	.02	.86	.03
68	4.05	64.91	7.03	.70	18.86	.54	1.23	.84	1.31	.03	.36	.05
69	13.72	41.88	3.92	1.56	30.84	.02	1.09	1.04	5.32	.21	.09	.06
71	6.78	62.19	2.45	----	24.56	.58	----	----	----	----	.28	----
72	----	59.76	2.64	.19	29.30	1.08	1.30	----	----	----	----	----
74	7.39	59.03	4.23	.19	23.41	1.18	.70	1.09	2.54	.06	.10	.01
75	2.14	84.97	1.31	.03	6.40	.66	1.86	.74	1.02	.00	.13	.92

The following analyses[1] of typical flint and plastic clays from Pennsylvania and other States show the variation in composition of clays of the same classification.

[1] Powell, E. P., Boiler furnace refractories; Bull. Am. Soc. Mech. Eng., vol.——, P 849.

Typical Analyses of Clay

	Flint					Plastic				
	Mo.	Penna.	Md.	Ohio	Ky.	Mo.	Penna.	Md.	N. J.	Ky.
Ignition	13.78	13.63	7.90	13.50	13.60	12.10	12.68	9.15	5.60	9.66
Silica	42.70	43.10	50.27	43.52	41.00	56.76	44.60	50.80	76.24	55.92
Alumina	39.72	39.40	39.40	37.86	37.22	26.57	37.35	37.37	15.76	24.71
Iron Oxide	1.14	1.35	1.86	1.79	5.78	1.60	1.17	0.63	0.52	4.19
Titania	2.22	2.01	------	1.51	2.00	1.75	2.16	------	1.68	1.52
Lime	0.13	0.13	0.36	0.44	0.34	0.44	0.30	0.08	0.26	0.34
Magnesia	0.29	0.08	0.01	0.66	1.01	0.17	0.42	0.14	0.29	1.01
Alkalis	0.22	0.20	0.53	0.80	1.57	0.10	1.57	1.80	0.23	1.57
Fusion, cone	34-35	33-34	33-34	33	32	30	32-33	31-32	30	20-26
" deg. Fahr	3182	3146	3146	3128	3101	3038	3115	3083	3038	2849
" deg. Cent	1750	1730	1730	1720	1705	1670	1713	1695	1670	1565

	Semi-Flint and Semi-Plastic						A Maryland Seam			
	Mo.	Penn.	N. J.	Ky.	Col.	Burley Mo.	No. 1	No. 2	No. 3	No. 4
Ignition	12.66	11.53	12.38	14.08	14.16	13.30	11.36	8.68	7.32	1.22
Silica	49.64	46.20	51.04	43.46	49.02	34.62	46.68	57.34	61.40	94.80
Alumina	33.69	36.33	32.31	37.45	34.78	48.08	36.32	28.56	26.28	3.40
Iron Oxide	1.30	1.65	1.29	1.19	0.72	1.09	2.59	1.58	1.16	0.22
Titania	1.56	2.16	1.92	2.80	0.90	2.28	2.01	3.45	1.44	0 52
Lime	0.31	0.18	0.37	0.30	0.39	0.25	0.07	0.17	0.13	0.11
Magnesia	0.43	0.27	0.34	0.64	0.24	0.56	0.46	0.13	0.54	0.15
Alkalis	0.37	1.72	0.12	0.93	0.37	0.44	0.32	0.71	1.12	0.35
Fusion, cone	32.33	32	32.33	32.33	32	33	32.33	28.29	29	32
" deg. Fahr	3115	3101	3115	3115	3101	3128	3115	2990	3002	3101
" deg. Cent	1713	1705	1713	1713	1705	1720	1713	1643	1650	1705

APPENDIX

The following description and tables are from a paper on The Fire Brick Materials of Pennsylvania, by George H. Ashley.[1]

Soft Clays

The use of soft clays for making fire brick without mixture with flint clays is confined mainly, if not entirely, to the western end of the State. There are two centers of such use, one around the mouth of Beaver River, the other on Monongahela River near Monongahela City.

In the Beaver district clay is obtained locally from below the Lower Kittanning or "B" coal. The part of the bed used is 6 to 8 feet thick, the lower part being too sandy. Brick from this clay is suitable for use in the upper part of furnaces where high resistance to abrasion is necessary. They will not stand the high heat of the bottom of the furnace. There are a half dozen or more plants in the Beaver district, some of which also use flint clays from the center of the State. Plants are located around Beaver, Rochester, and New Brighton, Conway Station, Monaca, Vanport, and elsewhere.

The fire brick plants on Monongahela River use the clays from the waste heaps or gob of mines on the Pittsburgh coal. This clay, which makes the parting between the main coal and the overlying "roof coal," is from 6 to 10 inches

1 Ashley, George H., The Fire Brick Materials of Pennsylvania: Jour. Amer. Ceram. Soc. Vol. 6, No. 7, July 1923.

thick. The clay is used principally for making sleeves, nozzles, and runners for steel works. It has been mined at Manown, Watson Station, and Courtney.

Soft clays used as a bond with flint clays are in general mined close by the fire brick plants wherever those plants are situated.

Flint Clays

Good flint clays are rather widely distributed over the coal measure area of the State. The leading districts are in Clearfield, Centre, Clinton, Fayette, Westmoreland, Clarion, Armstrong, Cambria, and Indiana counties, with scattered plants in other counties. Probably the most valuable of the clays is that at the base of the Allegheny formation or Mercer horizon. The Bolivar clay occurring beneath the Upper Freeport coal comes next, and the Clarion clay under the "B" coal is third. Locally flint clays occur under other beds and above the Upper Freeport coal. A brief reference to the principal producing areas by counties follows:

Armstrong County.—The Mercer clay has long been mined in northern Armstrong County at St. Charles, where it is 6 to 10 feet thick, including 2½ feet of flint clay. At the toe of Anthony's Bend, above Climax, the clay is only 75 feet above the creek and 12 feet thick, including both soft and hard clay. The Clarion clay is a semi-plastic clay one mile northeast of Kittanning. Both the Clarion, Lower Kittanning, and Upper Freeport clays are mined in this county, but only locally carry flint clay. Flint clay was formerly mined at Manorville from the Bolivar horizon. The soft clays of this country are much used for bonding flint clays, and are used alone to a small extent for fire brick.

Cambria County.—Cambria County has produced some flint clays from the Mercer horizon in South Fork district. The clay is up to 4½ feet thick, and overlain by a few inches of coal. Flint clays occur at the horizon of the Bolivar bed and within 100 feet above it, and have been tested around Johnstown and farther north in the county. Several firms at Johnstown are making fire brick, using both local clays and clay from South Fork.

Cameron, Elk, and Clinton Counties.—There are fire brick plants in Cameron, Elk, and Clinton counties, but the source of the raw material is uncertain, as these counties have not been studied in recent years in detail. Hard clay 4 to 9 feet thick, variously described as belonging to the Sharon horizon at the base of the coal measures, or at the Mercer horizon somewhat higher up, has been worked at Cameron, Cameron County, in the neighborhood of Benezette, between Benezette and Rock Hill, and on Laurel Run, in Spring Creek township, Elk County. The Mercer clay, or a clay at the base of the Allegheny formation, is being worked at Farrandsville and Queen Run, Clinton County, and a hard clay supposed to be under the Middle Kittanning or "C" coal is being mined on Tangascootack Creek in Clinton County.

Clarion County.—The Mercer fire clay has been mined at Climax and St. Charles on Redbank Creek, on the boundary between Clarion and Armstrong counties. The most widespread clay in Clarion County is the "Clarion" clay under the Lower Kittanning or "B" coal. This clay is fairly persistent over a belt 3 to 5 miles wide along Clarion River in the vicinity of Clarion town. It has been mined at Sligo and at several places near Clarion Junction and Piney, and its outcrops in the roads reveal its presence over a broad area. As seen in some of the strippings the flint clay appears to be very irregular, occurring in places as great irregular masses in the soft clay. The thickness ranges from 2 to 5 feet.

This clay is now being extensively mined 2½ miles southeast of Clarion on the Lake Erie, Franklin and Clarion Railroad near the Harvey mine on the Dean Klahr farm, by the Clarion Refractories Company. The flint clay will average 4 feet, with a maximum thickness of 9 feet. It is overlain by semi-flint 5 feet thick, and 20 feet above that is about 6 feet of soft clay under the Lower Kittanning coal. Clay has been mined at Lucinda 8 miles north of Clarion for 30 years or more. This clay is shipped to Ohio for furnace use. It is reported to be from 8 feet to a feather edge in thickness.

Clearfield County.—Probably the leading flint clay county of the State is Clearfield. Separate figures for fire clay are not available, but in 1920 the terra cotta and fire clay production in this county was valued at $8,087,900. This does not include the value of clay shipped for use out of the county. The principal deposits are in Ferguson, Pike, Bradford, Boggs, Decatur, and Karthaus townships. In Ferguson township the Mercer clay is being mined at Lumber City a short distance above river-level. The flint clay is 6 feet thick or more. In Pike township flint clay is mined at a number of places around Stronach where the "nodular" clay is from a knife edge to 6 feet thick, and the "block" clay below from 2½ to 7 feet thick. Up Anderson Creek above Clearfield in a number of mines the flint clay is from 2½ to 10 feet thick. On Hogback Run the bed is reported to show locally as much as 8 feet of nodular clay overlying 11 feet of block clay. In places this changes to as high as 11 feet of nodular clay over 7 feet or more of block clay.

Flint clay is found at several horizons around Clearfield but apparently is not so high grade as farther east. The works at Clearfield are therefore mainly on the soft clay, or are using flint clay shipped in. Fire clay is mined at many places along Clearfield Creek, including Clearfield Junction, where two beds have been mined, Krebs Station where the Clarion clay is being mined, Faunce, Chase, and other points. At most of these places the clay mined is at the Mercer horizon. The flint clay portion of the bed is from 2 to 6 feet thick, overlain by thin Mercer coal.

In Bradford township flint clay has been or is being mined at Barrett Station, Mineral Spring, Woodland, Bigler, and over wide areas south of the last two places, and outcrops at many other points in the township. Both the Mercer and Clarion beds are mined. The Mercer bed is the more persistent and valuable, having a maximum thickness of 10 or 12 feet, though the portion mined and the average thickness will commonly range from 2½ to 4 feet.

Flint clay has been found at many places in Boggs township, especially west and southwest of Blue Ball, and at many points in the Morgan Run drainage.

The northwest corner of Decatur township around Burley is a nest of mines. The Mercer clay here, as west of Blue Ball, is near the top of the hill and has been extensively stripped though most of the workings are underground. In general the flint clay of this district is from 6 to 8 feet thick, though locally reaching 12 to 15 feet.

Flint clay crops out or is found by drilling over a considerable area in eastern Woodward township. Around Westover in Chest township is a small area of flint clay under the Upper Kittanning or C′ coal.

Centre County.—Flint clay at the Mercer horizon has been worked from an early day at Sandy Ridge and Powelton in Centre County. The flint clay is from 2 to 4 feet thick, associated as usual with soft clay. Fire brick has also been made at Clarence and Orviston in the same county, but the writer has never examined the clay at these points.

Fayette and Westmoreland Counties.—The flint clay in these counties is localized in three districts. The first is where the Fayette anticline brings up rocks of Allegheny age on Youghiogheny River and Sewickley Creek. The second district is along the western foot of Chestnut Ridge where the same rocks are brought up to the surface by the upturning along the ridge. The third district is along Kiskiminitas River where the clay in the Allegheny formation is exposed again.

In the first district mining centers around Layton Station, the mines being in the Bolivar clay and in the clay below the Lower Kittanning coal. Some clay has also been mined about 130 feet above the Upper Freeport coal. At Layton there is from 8 to 12 feet of hard clay over soft clay, the whole bed having a thickness of 6 to 20 feet.

Mining on the western flank of Chestnut Ridge has extended for a long distance in Fayette County and in Westmoreland County to Conemaugh River. Among places of special note are Bailey's Point below Bear Creek Station, Henninger Mills near Dunbar, Pechin Station, Mt. Braddock, Lemont Furnace, and White House near the south State line.

The flint clay is mined from the Bolivar and Mercer horizons. At most of these places the flint clay has a maximum thickness of 12 or 15 feet. Mining as a rule has been confined to the outcrop because experience has shown that beyond the zone of weathering the clay contains too much iron, but within that zone the iron has been brought together in the form of "iron balls," which are easily separated. The type locality of the Bolivar clay is at Bolivar where Chestnut Ridge is cut by Conemaugh River, The flint clay has been mined here extensively and has a maximum thickness of over 20 feet. Clay has been mined still farther north in Indiana County along the west flank of Chestnut Ridge at the Mercer horizon and averages 11 feet thick. The clays from this belt along the western side of Chestnut Ridge have been used largely in making brick for building beehive coke ovens. The Bolivar clay has also been mined at Salina farther down Kiskiminitas River, the flint and soft clay together being from 6 to 13 feet thick. The clay is irregular in thickness, varying from 12 feet to 2 feet within the same mine.

Indiana County.—Clay 3 to 11 feet thick has been mined at Black Lick from the Mercer horizon; and on the west slope of Chestnut Ridge 1½ miles east of Black Lick.

There is little doubt but that detailed studies will reveal flint clays or soft clays suitable for refractory brick at many other places in the State.

CHARACTER OF CLEARFIELD COUNTY FLINT CLAY

When the writer was making a detailed geologic map of southern Clearfield County several years ago, samples of flint clay in the area were collected by Mr. J. H. Hance. These samples were tested by the United States Bureau of Standards. The results are given in the following tables.

SOURCE AND CHARACTER OF CLEARFIELD COUNTY FIRE CLAY SAMPLES

1. Jno. Brotherlin mine, Faunce. A refractory flint fire clay which retains a porous structure at 1475°C.

2. Good mine, Morgan Run. A refractory flint fire clay which retains a porous structure at temperatures up to 1475°C. Mixed with a plastic refractory clay it may be used in the manufacture of fire brick.

3. Faunce mine, Faunce. A refractory flint fire clay which retains a porous structure at temperatures up to 1475°C. Mixed with a plastic refractory clay it may be used in the manufacture of fire brick.

4. Cornwath mine No. 2, underlying coal, Cornwath. A fairly plastic buff burning fire clay which vitrifies at 1150°C and becomes vesicular at 1180°C. It may be used in the manufacture of porous building brick. Has no value in manufacture of refractories.

5. Soft clay, Krebs. A plastic buff burning fire clay which vitrifies at 1200°C. It may be used in the manufacture of buff colored building brick. It may be used in the manufacture of low grade refractories.

6 Shale bank, Krebs. A plastic buff burning clay of low refractoriness which vitrifies at 1175°C. It would be of value in the manufacture of building brick. It has no value in manufacture of refractories.

7. Ross mine, Lumber City. A refractory flint fire clay which retains a porous structure at temperatures up to 1475°C. Mixed with a plastic clay it may be used in the manufacture of fire brick.

8. Ross-Bloom mine, above Curwensville. A refractory flint clay which retains a porous structure at 1475°C, although its softening point (cone 32) is low for materials of this type. Has value in manufacture of refractories.

9. Hard clay mine, Stronach. A refractory flint clay which retains a porous structure at 1475°C. May be used in the manufacture of refractories.

10. Nodular clay, Stronach. A refractory flint fire clay which when mixed with a plastic refractory clay may be used in the production of fire brick.

11. Soft clay mine, Stronach. A buff burning plastic fire clay which vitrifies at 1150°C. It may be used in production of building brick, etc., but has no value in the manufacture of refractories.

12. Shimmel mine, Wallaceton. A very refractory flint fire clay which retains a porous structure at high temperatures. When mixed with a plastic clay it may be used in the manufacture of refractories.

13. Upper hard clay, Woodland mine, Woodland. Refractory flint fire clay which retains porous structures at high temperatures. May be used in manufacture of refractories.

14. Soft clay, Shimmel mine, Wallaceton. Buff burning fire clay of somewhat low plasticity and vitrifying at 1180°C. May be used in production of low grade refractories or of building brick.

15. C′ clay, middle hard, Plane mine, Woodland. Flint fire clay which remains porous at 1475°C, although its softening point (cone 31) is somewhat low for the production of high grade refractories.

16. Lower soft clay, Woodland mine, Woodland. Refractory plastic fire clay which burns to dense structure at 1450°C, and has a high softening point (cone 32) for a plastic clay. Has value as plastic bonding clay for manufacture of refractories.

17. Upper low grade hard clay, Woodland. Refractory flint clay which remains porous at 1475°C, although the softening point (cone 30) is too low for manufacture of No. 1 refractories.

18. Lower clay 16½ inches thick and 1 foot below A coal. Soisson mine, S. Sandy River, Bolivar, Westmoreland County. A refractory plastic fire clay vitrifying at 1350°C. This material may be used as bond clay in the manufacture of refractories.

Character of Clearfield County fire clays

Sample number	Molding behavior	Water of plasticity in per cent dry weight	Volume drying shrinkage in per cent dry volume	Softening point in Seger cones
1	Non-plastic	12.4	5.1	33+
2	Non-plastic	12.1	4.8	33
3	Non-plastic	12.3	4.8	33
4	Fair plasticity	18.8	13.7	25
5	Very fair plasticity	18.6	13.6	26
6	Good plasticity	----	----	8
7	Non-plastic	13.2	5.4	33
8	Non-plastic	13.7	5.5	32
9	Non-plastic	12.7	4.9	32+
10	Non-plastic	13.2	3.5	33
11	Very fair plasticity	20.3	14.1	15+
12	Non-plastic	13.3	5.9	33+
13	Non-plastic	12.2	4.6	33
14	Slightly plastic	18.1	13.0	29
15	Non-plastic	16.1	7.8	31
16	Fair plasticity	16.8	10.6	32+
17	Non-plastic	12.3	4.3	30
18	Very fair plasticity	18.2	12.6	29

Burning shrinkage of Clearfield County fire clays at different temperatures

No.	Degrees Centigrade										
	1000	1030	1060	1090	1120	1150	1180	1210	1240	1270	1300
1		12.1	12.2	12.9	13.7	15.5	16.3	16.8	17.2	17.2	17.2
2		4.0	5.7	7.0	7.6	7.5	8.9	9.4	10.2	10.7	11.3
3		9.8	10.8	11.3	12.1	12.6	12.5	12.8	12.0	11.1	9.9
4	5.6	7.8	10.1	13.5	15.3	16.5	8.1	2.2			
5		4.2	6.1	8.2	10.5	13.8	15.1	12.3	7.6	6.2	
6		1.0	5.1	10.3	14.7	16.9	18.6	18.8	18.0		
7	9.1	10.3	10.6	12.4	13.1	13.2	13.8	13.8	12.2	11.6	
8		9.0	10.4	11.8	12.5	12.9	12.3	12.4	12.6	12.6	11.3
9		12.5	13.3	14.0	15.2	15.9	16.1	16.5	16.3	15.9	15.0
10		2.8	3.3	3.8	3.9	5.4	7.2	7.6	8.2	8.4	8.6
11	5.4	8.5	12.0	16.1	18.6	20.4	8.0				
12	8.6	8.4	9.1	9.5	9.8	10.9	11.4	11.9	11.9		
13		11.5	13.0	13.4	14.9	15.4	15.7	15.8	16.6	16.6	16.6
14		5.4	8.5	11.3	14.2	16.5	16.1	8.8	4.2		
15		0.6	0.9	1.4	2.0	2.5	3.0	2.7	2.4	0.9	0.3
16		5.8	8.7	10.9	12.6	13.6		16.0	17.6	18.1	18.1
17		9.1	11.8	13.4	15.9	16.6	16.4	16.8	16.5	15.8	14.2
18	1.0	1.6	3.2	5.3	8.2	9.8	12.0	13.3	14.5	14.3	

Porosity of Clearfield County fire clays at different temperatures

Sample No.	Degrees Centigrade																	
	1000	1030	1060	1090	1120	1150	1180	1210	1240	1270	1300	1325	1350	1375	1400	1425	1450	1475
1	----	25.5	25.4	25.7	25.1	24.2	23.3	23.2	23.3	22.9	22.0	22.1	22.7	22.1	22.3	21.4	----	20.9
2	----	30.0	29.7	29.3	29.4	28.9	28.6	27.4	27.4	26.9	25.7	25.9	26.3	26.4	26.1	25.8	----	25.1
3	----	25.8	25.7	25.2	24.6	24.7	23.8	24.5	24.2	24.1	24.4	22.3	22.4	23.4	24.7	21.6	21.9	21.8
4	22.7	21.8	18.4	15.4	13.0	9.6	12.7	17.7	21.8	----	----	----	----	----	----	----	----	----
5	----	26.1	24.5	22.3	19.6	16.4	13.2	11.0	9.6	8.6	8.2	9.6	10.8	8.1	8.3	----	7.2	8.7
6	----	28.0	24.9	19.2	13.9	12.4	9.6	8.9	7.6	16.8	----	----	----	----	----	----	----	----
7	25.4	25.8	24.9	24.4	24.3	23.4	23.1	22.6	22.2	22.0	----	21.3	21.9	20.8	21.1	20.4	19.1	19.0
8	----	27.1	26.5	26.4	26.5	26.4	20.0	20.0	25.5	24.4	24.6	22.1	23.8	23.3	23.4	23.4	----	22.5
9	----	25.7	25.8	25.0	24.6	23.5	24.1	22.9	23.7	23.5	23.8	22.7	23.1	22.0	22.4	22.2	22.2	0.8
10	----	33.9	33.8	32.8	34.2	34.1	33.8	32.9	33.1	33.1	32.4	32.7	32.0	32.0	33.7	32.6	----	33.4
11	24.9	23.5	20.8	15.7	9.0	6.0	6.9	21.2	----	----	----	----	----	----	----	----	----	----
12	28.0	27.6	25.1	27.1	27.5	27.9	27.2	26.7	25.9	----	26.5	27.3	27.8	27.2	26.9	26.3	26.1	24.0
13	----	25.8	25.8	24.9	24.2	23.7	23.2	23.7	23.0	23.0	22.5	22.3	22.1	21.7	21.4	----	21.3	20.3
14	----	25.2	23.7	20.7	17.8	13.7	10.6	10.9	11.3	12.1	----	----	----	----	----	----	----	----
15	----	29.4	29.4	29.6	30.4	29.8	29.9	30.4	29.5	29.7	29.7	29.0	29.0	29.3	----	28.8	----	27.8
16	----	27.4	25.7	24.1	22.5	21.1	20.1	19.9	19.0	18.4	18.3	14.6	14.8	14.6	13.3	12.0	----	9.7
17	----	26.6	25.5	25.4	25.1	24.5	23.6	23.8	23.9	23.3	22.8	19.4	19.7	20.0	20.1	21.5	----	19.9
18	32.3	26.7	24.7	23.3	21.0	18.2	16.7	14.2	12.7	11.1	----	5.3	2.9	2.3	3.1	5.3	3.8	1.6

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